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30/20 GHz FIXED COMMUNICATIONS SYSTEMS SERVICE DEMAND ASSESSMENT

by: R. B. GAMBLE
H. R. SELTZER
K. M. SPETER
M. WESTHEIMER

prepared for:

NASA

LEWIS RESEARCH CENTER

U.S. TELEPHONE AND TELEGRAPH CORPORATION ITT

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16. Abstract

Demand for telecommunications services is forecast for the period 1980-2000, with particular reference to that portion of the demand associated with satellite communications. Overall demand for telecommunications is predicted to increase by a factor of five over the period studied and the satellite portion of demand will increase even more rapidly. Traffic demand is separately estimated for voice, video and data services and is also described as a function of distance traveled and city size.

The satellite component of projected demand is compared with the capacity available in the C and Ku satellite bands and it is projected that new satellite technology and the implementation of Ka band transmission will be needed in the decade of the 1990's.

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PREFACE

This study is the product of a team of over twenty professionals drawn from various parts of ITT and several subcontracting organizations, whose contributions are hereby gratefully acknowledged. The authors would like to especially recognize the dedicated efforts of L. Saporta and R. Waxman of Data Industries, Corp. in the technical effort, writing and editing of this study report. The continuing guidance and support of J. D. Ash, W. G. Donaldson and D. J. Marsh of ITT have greatly enhanced the professional quality of the finished product.

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SUMMARY

This report presents a forecast of demand for telecommunications services through the year 2000 with particular reference to demand for satellite communications. Estimates of demand are provided for Voice, Video, and Data services and for various subcategories of these services. The results are converted to a common digital measure in terms of terabits per year and aggregated to obtain total demand projections.

The portion of total demand that is likely to be transmitted via satellite facilities is estimated and compared with the capacity of C and Ku band satellites expected to be in orbit over the time frame covered by the study. Overall demand is expected to grow by a factor of about five in this period, and that portion likely to be a candidate for satellite transmission will grow by an even larger factor. This demand growth is projected to outpace available C and Ku band satellite capacity before 1990 and it is likely that new satellite technology will be required to respond to the growing demand.

The report also presents the geographical distribution of traffic with respect to city size, and with respect to distance traveled. Roughly 50 percent of the traffic originating in urban areas comes from cities with populations of over 100,000 people. Of that traffic traveling outside of the immediate local area (nominally beyond 200 miles), 50 percent is estimated to travel more than 700 miles and 37 percent more than 1000 miles.

The demand forecasts are organized by user type with separate categories for Private Individuals, Business, Government, and Institutions. As might be expected, Business uses dominate demand throughout the period of the study.

Demand is also evaluated as a function of the reliability of the communications offering and that sector of demand that requires real-time as opposed to deferred modes of transmission is identified.

Projections are made of the cost of terrestrial tails involved in distributing satellite traffic to users. The cost of terrestrial facilities is also estimated for comparison with costs of satellite communications. The sensitivity of communications demand to price variation is evaluated.

A study of Atlanta, as representative of a large metropolitan area with growing telecommunications demands, is included. Projections are made of the type and volume of telecommunications demand that will originate or terminate in the Atlanta Region.

1.0 INTRODUCTION

This report presents the results of a study of telecommunications demand performed under NASA Contract number NAS3-21366 (Ref. 1.0-1). A separately bound Executive Summary provides an overview of the major results obtained.

To insure the timely availability of appropriate satellite technology for future delivery systems it is necessary to assess the demand for telecommunications services likely to develop during the 1980 to 2000 time frame. This report projects demand for telecommunications services through the year 2000 with particular reference to the need for satellite communications. Of particular interest is the potential role of 30/20 GHz systems in meeting the anticipated needs.

Demand is forecast for each of the major telecommunications services and the projections are supplemented by supporting data concerning costs, reliability, and the geographical distribution of traffic.

1.1 RELATED WORK

This study is one of four related studies. Two of these are directed primarily to demand analysis. In addition to the present ITT study, demand forecasts were also produced by Western Union under NASA Contract number NAS3-21359. Both of these demand studies explore the potential need for new satellite technology to meet forecasted telecommunications demand.

The other pair of studies were conducted by Ford Aerospace and Communications Corp. under NASA Contract NAS3-21362 and Hughes Aircraft Corp. under NASA Contract NAS3-21367. These two studies are systems oriented and define the satellite technologies that are most likely to be cost effective in satisfying projected demand.

1.2 SCOPE

The study forecasts the demand for telecommunications services through the year 2000, with a primary focus centering on that portion of demand which offers a suitable target for transmission via satellite. The study therefore emphasizes long distance communications needs, i.e., communications which extend beyond local boundaries, nominally taken to be 200 miles.

DEMAND FORECASTS BY SERVICE TYPE

The basic demand forecasts of this study are organized by type of service, the major categories of which are Voice, Video, and Data. Important subcategories of each of these services are identified and traffic demand for each is estimated.

GEOGRAPHIC DISTRIBUTION OF TRAFFIC

The study also investigates the geographical distribution of traffic, both as a function of distance traveled and in relation to city size. Maps showing traffic density over the contiguous states are presented for each of the benchmark years 1980, 1990, and 2000.

SENSITIVITY OF DEMAND TO COST

The elasticity of demand in response to changes in price is discussed in terms of telecommunications as a whole, and with respect to a limited segment of communications whose price behavior can vary with respect to that of telecommunications in general.

USER MARKET IDENTIFICATION

Sortings of the basic demand forecasts are presented to indicate the fraction of traffic demand generated by various user categories. The user categories are: Private Individuals, Business, Government, and Institutions.

CASE STUDY OF A METROPOLITAN AREA

The study also includes a description of a large metropolitan area. The Atlanta Region was selected for this purpose as being one of strong economic growth with rapidly expanding needs for communications facilities. The development of communications patterns in this region is typical of those urban areas undergoing substantial growth in population and in economic activity, and it is from these areas that the bulk of traffic demand may be expected.

SERVICE COSTS

Communications is a commodity with an economic price tag and estimates are provided for the current and projected costs of telecommunications. The estimates include projections for the costs of terrestrial tails involved in distributing satellite traffic to users. Costs are also provided for terrestrial transmission facilities so that the costs of these facilities and those of projected satellite communications facilities may be compared.

DEMAND AS A FUNCTION OF RELIABILITY

Rain attenuation is an important design consideration for 30/20 GHz satellite communications. The cost of such a system is significantly dependent on reliability objectives. This study examines demand for satellite communications as a function of reliability for each of the service categories and subcategories. The degree of user acceptance at each level of reliability is established and the effectiveness of offering price reductions in compensation for reduced levels of reliability is discussed.

REAL TIME VS DEFERRED COMPONENTS OF DEMAND

Another important factor in telecommunications system design is the degree to which traffic can be deferred rather than immediately transmitted. A large component of deferred traffic permits more efficient use of the communications facilities by reducing peak loads. The demand forecasts of this study consider the real time and deferred transmission needs of the user community. That component of the demand requiring real time service is estimated, as are those components that can tolerate various delays ranging from minutes to one day.

SATELLITE CAPTURE

The portion of the total traffic that is likely to be carried by satellites for each of the benchmark years is estimated and expressed in terms of the number of satellite transponders that will be needed. This, in turn, is compared with the number of transponders that will be available in the C and Ku bands to arrive at the year in which C and Ku capacity would become saturated in the absence of new satellite technology.

1.3 METHODOLOGY

A comprehensive literature survey of prior studies of domestic communications demand was conducted. This literature search was supplemented by visits to organizations having expertise in particular areas of telecommunications. Information was collected relative to demand, present and potential services, growth trends, geographical and demographic factors, developing technology, and costs. This information supplemented in-house data sources and was used in forming the basic demand projections. Sources are cited as appropriate throughout the report.

The three major categories of service (Voice, Video, and Data) were each divided into a number of subcategories. Demand projections for each subcategory were arrived at for the benchmark years 1980, 1990, and 2000. In forming these projections a variety of forecasting methods were used to best employ the differing

types of information available for each subcategory. Initial demand projections were developed in measurement units most appropriate to each particular subcategory (e.g. call-seconds, video circuits, bits, etc.). These were later placed on a common basis by converting to bits so that results could be compared and aggregated.

Estimates for the efficiency of usage of the communications plant, peaking factors, capture ratios, and other parameters of interest were also developed on a subcategory basis and later aggregated to arrive at totals. This procedure was followed in evaluating the acceptability of various levels of reliability, the relative needs for real time vs. deferred service, and the number of satellite transponders needed to satisfy the projected demand.

2.0 DEMAND FORECASTS FOR TELECOMMUNICATIONS SERVICES

This section contains the basic demand forecasts provided by this study. Demand is projected for Voice, Video and Data services for each of the benchmark years 1980, 1990 and 2000.

Each service is divided into categories and subcategories of traffic and demand for each is separately estimated. The units chosen to express demand vary from category to category as suitable to the particular component of traffic under consideration. To permit later comparison and aggregation of results, both within each service, and for demand as a whole, the demand forecasts are then converted to a common digital measure and expressed in terms of terabits per year. Further conversions to data rates during the busy hour and the subsequent estimation of the number of satellite transponders needed to satisfy demand are reserved for Section 6.

The present section also discusses the geographical distribution of traffic as a function of distance travelled, and as a function of city size. Maps are provided projecting the density of traffic per hundred square miles over the contiguous United States.

The effect of cost on demand is discussed. Results are cited for the price elasticity of demand in the relatively inelastic case of telecommunications as a whole, and for the more elastic situation in which a limited segment of communications (such as satellite transmission) is compared with the remainder of the communications plant.

2.1 VOICE SERVICES DEMAND

In this section the growth of voice traffic is presented and projected to the year 2000. The projections are made separately for the three major categories of voice traffic defined in 2.1.1 below, and then combined to give an overall voice service trunking requirement projection to the year 2000.

Since, of all the modern telecommunication services, the voice services most directly meet the basic human need to communicate, their growth is directly related to population, social factors and business activity. Unlike data and video services, technological innovations are deemed to play a minor role in the growth of voice services compared to population growth, social and business activity factors and regulatory actions.

Since population and business activity growth as well as sociological patterns do not change suddenly, the growth in voice services demand also exhibits a corresponding inertia. Voice services growth is, therefore, more predictable than the growth in data and video services. The prediction uncertainty inherent in the voice traffic projection is related more to the difficulty in predicting business activity and regulatory trends than to any postulated technological innovations.

2.1.1 CATEGORIES OF VOICE TRAFFIC

Only those categories which represent a significant share of the voice traffic were considered in projecting the growth of this service demand. These are

- Message Telephone Service (MTS)
- Wide Area Telephone Service (WATS)
- Private Line

Voice services which contribute less than one percent to the total demand (e.g. audio program transmission, trunked mobile radio) have a negligible impact on the overall facilities demand and, therefore, were not considered in this study.

2.1.2 MESSAGE TELEPHONE SERVICE (MTS)

The Message Telephone Service is provided by the telephone common carriers to their customers on a dial-up basis over common user telephone networks. Voice traffic over these networks is originated by:

- Individuals residing in households
- Individuals associated with a business, institutional, or government establishment

Machine-originated voice messages form a negligible part of the total number of voice messages generated. Conversations generated by using telephone sets have therefore been chosen as the basic unit for the projection of voice traffic and trunking requirements.

In view of the fact that the "originators" of conversations can be thought of variously as individuals, households, business establishments, and telephone sets, the past growth of all of these units was determined and correlated with the history of long distance (LD) telephone conversations for the purpose of establishing valid correlation factors. Those "units" showing good correlation with the growth in LD conversations were then used in the projection of LD traffic growth estimates.

To project voice circuit requirements, the total LD traffic volume must be known. This means that, in addition to the number of LD conversations per year, the average duration of an LD conversation must be determined. Furthermore, the worst case traffic volume situation, commonly referred to as the peak hour traffic, defines the trunking requirements and, therefore, must be calculated.

Since residential and nonresidential MTS traffic patterns are quite different, with peaks occurring at different times of the day, the total traffic volume in the peak hour was separated into residential and nonresidential peak hour traffic. The nonresidential peak hour traffic is referred to as the business traffic although it also includes government and institutional traffic. The diurnal traffic patterns of these two components, however, largely follow those of the business traffic.

The following paragraphs discuss those parameters which correlate with LD toll call growth. Total LD conversations per year were found to correlate best with population and household figures, but historic data and growth projections for GNP and the number of residential and business telephones is also presented. This is done for two reasons:

- Statistics of toll calls separated into residential and business groupings are not directly available. Therefore the correlation of total LD calls against population or household figures requires these additional statistics.

- The difference in growth rates of the number of business and residential telephones is used to project the current business/residential LD conversations mix to the year 2000.

2.1.2.1 Demographic and Economic Factors

The historical and projected growth in the number of residential and business telephone main stations is related to certain basic demographic and economic parameters. A number of these parameters were therefore studied to determine their correlation with the historical growth in number of telephones and LD calling rates. The purpose of this was to find those parameters whose performance may be used to project the growth in telephones and LD call volume.

The parameters examined were:

- Population
- Households
- Gross National Product (GNP)
- Population sorted by age brackets
- Disposable personal income
- Employment figures

It was found that, of all the above factors, population, the number of households, and GNP were the most promising approaches for projecting the growth and the number of phones and LD call volume. The residential sector of the MTS voice service proved to be well correlated with both population growth and growth in the number of households. In the business sector the GNP proved to be the best correlating factor. The other demographic and economic factors examined are related to the above three primary factors and therefore are of little additional significance. The degree of correlation and the extent to which the primary factors were used in forecasting the number of telephones and LD call volume is discussed in more detail below.

Population growth to the year 2000 is shown in Figure 2.1-1. The historical part of this curve, up to and including fiscal year 1976, is based on population statistics gathered from a variety of sources (Ref. 2.1-1, 2.1-2, 2.1-3). The projected part of the curve, beginning with July 1976, was obtained from data developed by the Bureau of the Census (Ref. 2.1-4) based on population growth scenarios and are designated as follows:

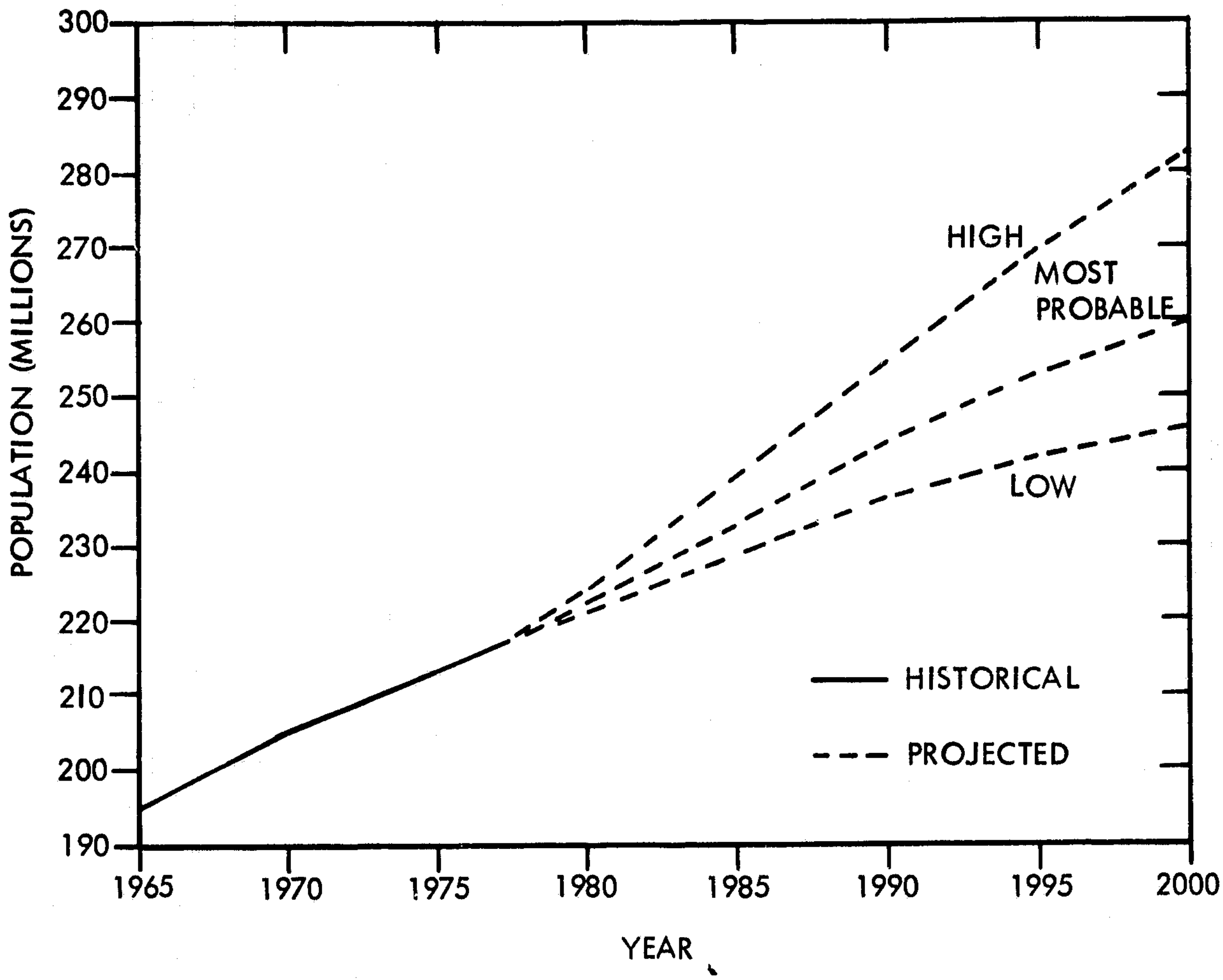

FIGURE 2.1-1. U.S. POPULATION - 1965 TO 2000

* Series I (high)
* Series II (most likely)
* Series III (low)

Historical data on the number of households was obtained from the Statistical Abstract of the United States (Ref. 2.1-1) and from Department of Commerce data (Ref. 2.1-5). Projections were obtained from Bureau of Census data (Ref. 2.1-6). Projected household growth is shown in Fig. 2.1-2.

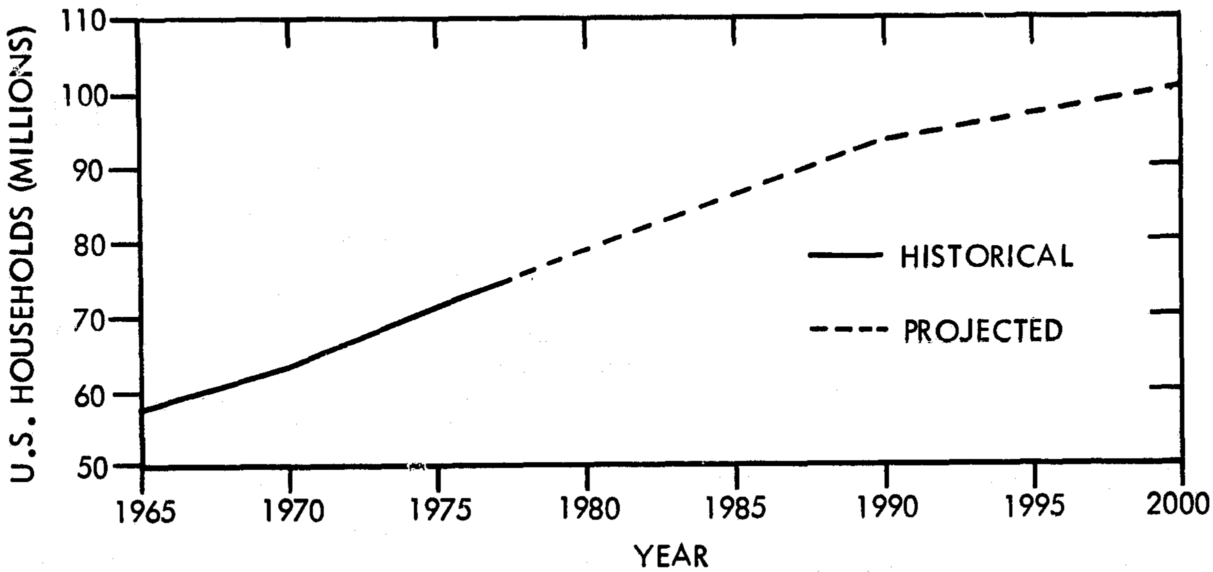

FIGURE 2.1-2. U.S. HOUSEHOLDS - 1965 TO 2000

It is of interest to note that the growth rate in projected number of households exceeds that of the overall population. This is indicative of a trend, already quite noticeable today, to form households prior to forming a family, i.e. an increasing number of single households.

Historical data related to the GNP (in terms of 1972 dollars) through 1977, and projections to the year 2000, are shown in Figure 2.1-3. As in the case of population, a low, most likely, and high scenario are shown. The GNP historical data was obtained from the Statistical Abstract of the United States (Ref. 2.1-7). As in the case of population, GNP projections to the year 2000 were compiled by the ITT Business Economics Department using U.S. Bureau of Economic Analysis data and ITT in-house analysis. Additional data concerning employment figures, disposable income, and price deflator data was obtained from Ref. 2.1-5 and 2.1-7 and from the National Planning Association (Ref. 2.1-8).

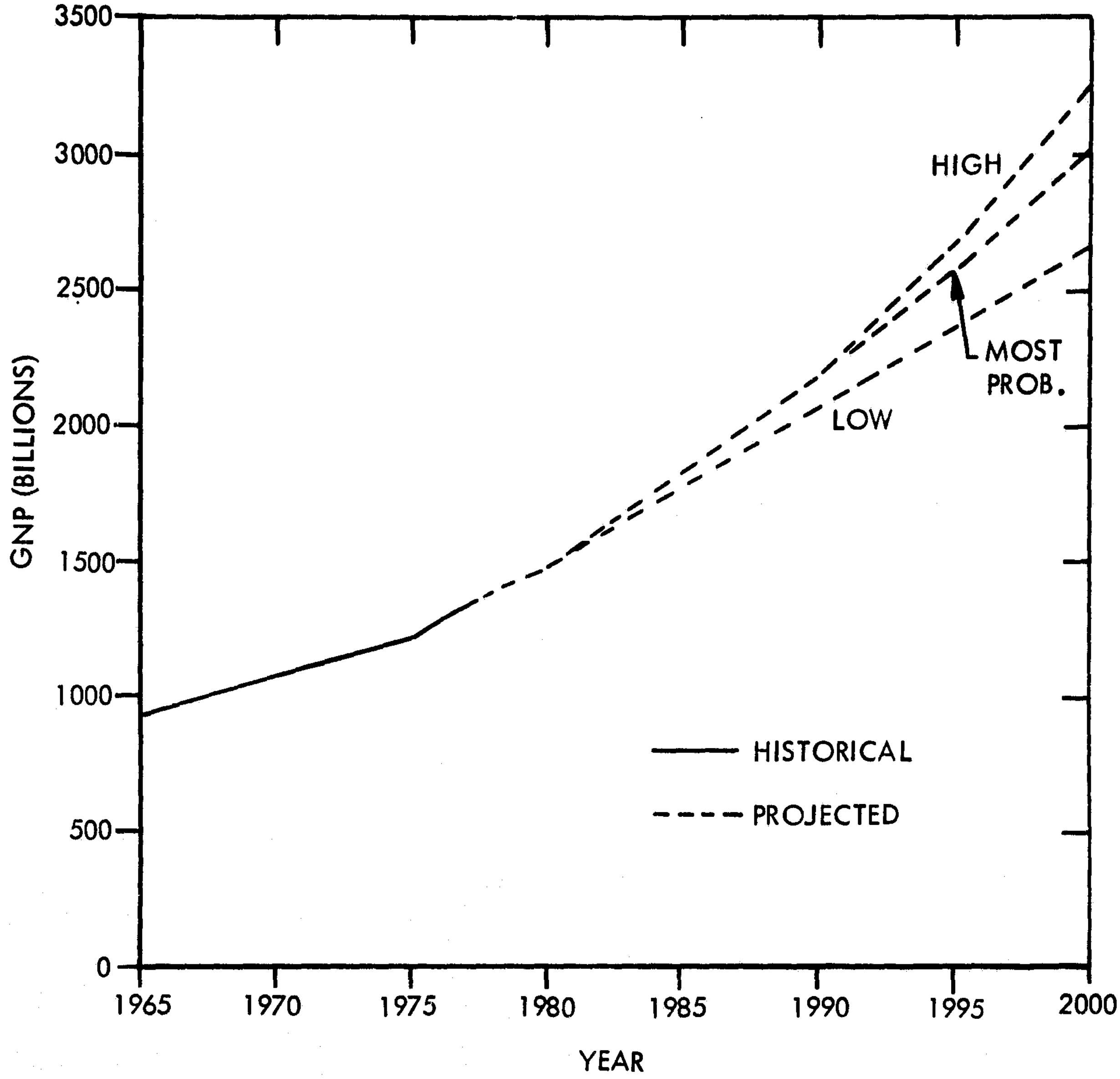

FIGURE 2.1-3. GROSS NATIONAL PRODUCT - 1965 TO 2000 (1972 DOLLARS)

Table 2.1-1 summarizes the most likely population estimates and their compound annual growth rates. Table 2.1-2 summarizes GNP in terms of 1972 dollars together with estimates for price deflator values appropriate to each decade.

TABLE 2.1-1. POPULATION SIZE AND COMPOUND ANNUAL GROWTH RATE

	1970-1980	1980-1990	1990-2000
Population at end of decade (millions)	222	244	260
Population growth rate during decade (percent)	0.8	0.9	0.7

Sources: U.S. Bureau of Census
ITT Business Economics Dept.

TABLE 2.1-2. GNP, COMPOUND GROWTH RATES, AND PRICE DEFLATORS (REFERENCED TO 1972 DOLLARS)

	1970-1980	1980-1990	1990-2000
GNP at end of decade (billions)	1492	2176	3025
GNP growth rate during decade (percent)	3.3	3.8	3.3
Price deflator during decade (percent)	6.6	5.7	4.1

Sources: U.S. Bureau of Economic Analysis
ITT Business Economics Dept.

2.1.2.2 Number of Telephones

While forecasts of the number of LD conversations are based partly on the correlation against projected growth in population and GNP and partly on extrapolation of historical LD call volume, information concerning the growth in the number of telephone main stations and the mix between residential and business telephones, is also germane to this study.

To study the impact of changing events and technical and regulatory climate on the baseline forecast, the number of telephone main stations and their growth rate are key elements in the analysis of LD call volumes. In addition, knowing the volume of residential and business telephone main stations as well as the business and residential LD call volumes provides the means to calculate LD calls per telephone for the residential and business sector. In addition, the difference in the growth rates of residential and business main stations is needed to project the mix of residential and business LD call volume. As stated in paragraph 2.1.2, this mix is not a directly available statistic but rather one that has to be derived.

The main station telephone count used in this section includes all telephones listed in the various statistics compiled by the common carriers and the Federal Communications Commission with the exception of extension telephones. This exclusion is based on the premise that an ordinary extension phone is not an independent generator of LD calls. Extension telephones, particularly in the residential sector, are an indication of number of persons per household. As will be shown in the following section, the LD call projections were primarily based on population. Including extension telephones in the overall telephone count, and using the number of LD calls per telephone as a call determining parameter, results in double-counting. The count does, however, include PBX telephones since those, used overwhelmingly in the business sector, generate LD traffic in the same manner as main station telephones.

The first step to compile data on the number of main station telephones from 1960 through 1977 was to examine Tables 16 and 17 of the Common Carrier Statistics (Ref. 2.1-9). Table 16 of this document shows statistics on all companies subject to annual FCC reporting requirements, with Bell System data summarized separately. Table 17 presents statistics on companies not subject to such reporting requirements. The sum of the number of telephones derived from these tables was compared to the number of telephones listed in the AT&T publication "World's Telephones" (Ref. 2.1-10). It was found that, using the Common Carrier Statistics, a shortfall of approximately six percent resulted. Furthermore, the data presented in the Common Carrier Statistics does not provide a distinction between residential and business main stations, a statistic important to this effort. While fragmentary data concerning this mix could be obtained from various sources (Refs. 2.1-11,12), a more comprehensive set of statistics was available from AT&T's "Construction Budget Material Forecast" (Ref. 2.1-13) and from the "Independent Telephone Statistics" (Ref. 2.1-14). The latter document covers more than ninety percent of all independent telephone companies. The historical telephone population statistics shown in the following tables was compiled using the above cited references.

The growth in the number of residential and business main telephones is shown in Table 2.1-3. The table provides data for the Bell System and the Independents and the share each has in each category.

Excluding somewhat higher growth figures for the 1965 to 1970 period, the overall growth in main telephones appears to be a steady 2.9% per year for the Bell System and approximately three percent for all companies. Growth rates for the Independents sector of the market are somewhat higher, a possible result of population and business movement away from urban areas (where the Bell System holds the majority of franchises) into suburban and exurban rural areas where a larger share of the independent telephone companies are found. The growth in business main telephones between 1970 and 1977 is somewhat higher than that of the growth in the residential sector. This difference in growth is an indication of the start of saturation of the residential market, the increasing pace of business activity, and the increasing reliance of business on communications.

The Bell System share of the total number of main telephones has decreased slightly from 84.3 percent of the total in 1965 to 81.4 percent in 1978. Throughout the entire period, the Bell System has consistently maintained a larger share of the business market than of the residential market. Bell's market share loss to the Independents between 1965 and 1978 is approximately three percent in both the residential and business sectors.

For the Bell System, the residential/business main telephone mix is at a stable 68%/32% for the 1970-1978 period. The independent companies' share of residential main telephones is somewhat higher than that of the Bell System, and slightly less stable. The Independents residential/business average mix for this period is 76.5%/23.5% with a 1.2% increase in residential share over the 1970 to 1978 period.

To project the number of residential and business main telephones three approaches were taken. The first was to use a proxy factor, i.e. one whose growth correlates well with the growth in number of main telephones, and for which projections are available. The second approach projected historical growth curves by means of linear or log-linear regression techniques. The third approach used a modification of the linear regression technique, which examined the growth rates resulting from regression analysis, applied a "test of reason" to them considering postulated demographic, sociological and economic trends, and modified these growth rates as indicated. It was found that a combination of all three techniques was the best procedure, with the correlation technique providing the input for the required modification of the regression technique.

TABLE 2.1-3. GROWTH IN RESIDENTIAL AND BUSINESS MAIN TELEPHONES

YEAR	TOTAL MAIN TELEPHONES Millions of Tels. + % Share						RESIDENTIAL MAIN TELEPHONES Millions of Tels. + % Share						BUSINESS MAIN TELEPHONES Millions of Tels. + % Share					
	Bell		Indep.		Total		Bell		Indep.		Total		Bell		Indep.		Total	
	Mill.	%	Mill.	%	Mill.	%	Mill.	%	Mill.	%	Mill.	%	Mill.	%	Mill.	%	Mill.	%
1965	57.4	84.3	10.7	15.7	68.1	100	39.0	82.5	8.3	17.5	47.3	100	18.4	88.5	2.4	11.5	20.8	100
1966	59.9	84.0	11.4	16.0	71.3	"	40.7	82.2	8.8	17.8	49.5	"	19.2	88.1	2.6	11.9	21.8	"
1967	62.2	83.8	12.0	16.2	74.2	"	42.3	82.0	9.3	18.0	51.6	"	19.9	88.1	2.7	11.9	22.6	"
1968	64.7	83.5	12.8	16.5	77.5	"	44.0	81.6	9.9	18.4	53.9	"	20.7	87.7	2.9	12.3	23.6	"
1969	67.4	83.3	13.5	16.7	80.9	"	45.8	81.5	10.4	18.5	56.2	"	21.6	87.4	3.1	12.6	24.7	"
1970	69.2	83.2	14.0	16.8	83.2	"	47.0	81.3	10.8	18.7	57.8	"	22.2	87.4	3.2	12.6	25.4	"
1971	71.1	82.9	14.7	17.1	85.8	"	48.2	80.9	11.4	19.1	59.6	"	22.9	87.4	3.3	12.6	26.2	"
1972	73.8	82.6	15.5	17.4	89.3	"	50.0	80.8	11.9	19.2	61.9	"	23.8	86.9	3.6	13.1	27.4	"
1973	76.1	82.4	16.3	17.6	92.4	"	51.6	80.5	12.5	19.5	64.1	"	24.5	86.6	3.8	13.4	28.3	"
1974	78.0	82.1	17.0	17.9	95.0	"	52.8	80.2	13.0	19.8	65.8	"	25.2	86.3	4.0	13.7	29.2	"
1975	79.7	81.9	17.6	18.1	97.3	"	54.1	80.1	13.4	19.9	67.5	"	25.6	85.9	4.2	14.1	29.8	"
1976	81.8	81.6	18.4	18.4	100.2	"	55.4	79.8	14.0	20.2	69.4	"	26.4	85.7	4.4	14.3	30.8	"
1977	84.2	81.5	19.1	18.5	103.3	"	56.9	79.7	14.5	20.3	71.4	"	27.3	85.6	4.6	14.4	31.9	"
1978	86.6	81.4	19.8	18.6	106.4	"	58.4	79.6	15.0	20.4	73.4	"	28.2	85.5	4.8	14.5	33.0	"
% Growth/Year																		
'65-70	3.8%		5.5%		4.1%		3.8%		5.4%		4.1%		3.8%		5.9%		4.1%	
'70-75	2.9%		4.7%		3.2%		2.9%		4.4%		3.2%		2.9%		5.6%		3.2%	
'75-76	2.6%		4.5%		3.0%		2.4%		4.5%		2.8%		3.1%		4.8%		3.4%	
'76-77	2.9%		3.8%		3.1%		2.7%		3.5%		2.9%		3.4%		4.5%		3.6%	
'77-78	2.9%		3.7%		3.0%		2.6%		3.4%		2.8%		3.3%		4.3%		3.4%	

The number of residential main telephones correlated closely with population and the number of households. Using GNP as a proxy factor, however, does not correlate as well for projecting residential telephones, and as a result, was not used.

The results of the projection of residential telephones on the basis of correlation with number of households, with population, and on the basis of a linear regression are shown in Table 2.1-4.

TABLE 2.1-4. PROJECTION OF RESIDENTIAL MAIN TELEPHONES (COMPARISON OF PROXY FACTOR AND REGRESSION METHODS)

	RESIDENTIAL MAIN TELEPHONES (MILLIONS)		
YEAR	CORRELATION WITH NUMBER OF HOUSEHOLDS	PROJECTION CORRELATION WITH POPULATION	BASED ON LINEAR REGRESSION
1980	78.2	77.1	77.6
1990	98.5	100.2	97.5
2000	107.6	118.5	117.3

This comparison shows that for the year 2000 the maximum difference between the three methods is approximately ten percent. A comparison of Tables 2.1-1 and 2.1-3 shows that, although the correlation between households and telephones is good, the telephone growth rate has historically outpaced the population growth rate. On that basis, a new growth rate mechanism based on factors shown in Tables 2.1-3 and 2.1-4 was postulated. This growth scenario and the resulting projections for the number of residential main telephones are shown in Table 2.1-5.

TABLE 2.1-5. PROJECTION OF RESIDENTIAL MAIN TELEPHONES (MODIFIED GROWTH SCENARIO METHOD)

YEAR	% ANNUAL GROWTH IN NUMBER OF HOUSEHOLDS	EST. ANNUAL GROWTH IN NO. OF RESIDENTIAL MAIN TELEPHONES (%)	NO. OF RES. MAIN TELEPHONES (MILLIONS)	
1970-75	2.3	3.2 (HISTORICAL)	1975	67.5
1975-80	2.1	3.0 (HIST.& EXTRAP)	1980	78.3
1980-85	1.9	2.8 (NEW SERVICES)	1985	89.9
1985-90	1.6	2.8 (NEW SERVICES	1990	103.2
1990-95	0.6	2.0 (NEW SERV.&SAT)	1995	113.9
1995-2000	0.7	1.5 (SATURATION)	2000	122.7

A similar approach was taken in projecting business main telephones (Table 2.1-6). However, in this case, a projection on the basis of a direct correlation with GNP resulted in growth rates which, on the basis of past history, were considered unreasonably high, whereas linear regression techniques resulted in unreasonably low growth rates. In fact, none of the major economic and demographic parameters which were examined provided as good a correlation with business telephones as households and population figures did with residential telephones. This is in

TABLE 2.1-6. PROJECTION OF BUSINESS MAIN TELEPHONES - MODIFIED GROWTH SCENARIO METHOD

YEAR	% INCREASE IN 1976 GNP	ESTIMATED % ANNUAL GROWTH IN NUMBER OF BUSINESS MAIN TELEPHONES	NO. OF MAIN BUSINESS TEL.	
			YEAR	MILLIONS OF TEL.
1970-75	2.3	3.3 (Historical)	1978	33.0
1975-80	4.4	3.5 (Hist. & Extrap.)	1980	35.4
1980-85	4.1	3.8 (New Services)	1985	42.6
1985-90	3.6	3.5 (New Services)	1990	50.6
1990-95	3.4	3.3 (Saturation)	1995	59.5
1995-2000	3.3	3.0 (Saturation)	2000	69.0

part due to the fact that telecommunications constitute only a fraction of the GNP and that population growth is considerably slower than the projected growth in GNP. Therefore, neither GNP nor population could be expected to be a reliable proxy factor. Furthermore, as the use of electronics in business becomes more prevalent and more sophisticated, one could expect a moderate displacement of the telephone by other electronic communications means such as facsimile, communicating word processors, and electronic mail equipment.

In view of these factors, a growth rate scenario falling slightly below projected GNP growth, but above projected population growth, was developed. This scenario, and the resulting projections in the number of business main telephones, are shown in Table 2.1-6. The projection of residential and business main telephones using the modified growth method is shown in Figure 2.1-4.

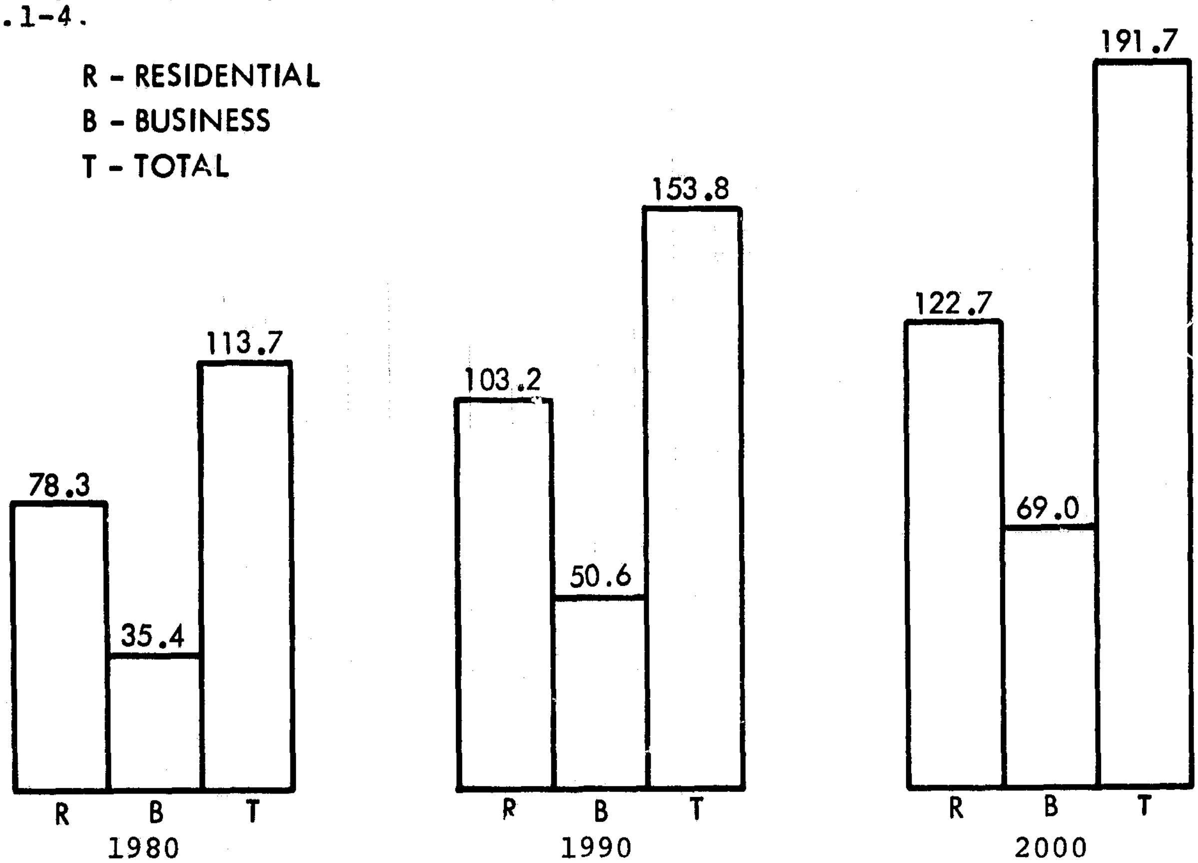

FIG. 2.1-4 RESIDENTIAL AND BUSINESS MAIN TELEPHONES (Millions)

2.1.2.3 Long Distance (LD) Call Projections

The historical data presented in this section is based primarily on information obtained from the Statistics of Communications Common Carriers (Ref. 2.1-9), the World's Telephones (Ref. 2.1-10), and the Independent Telephone Statistics (Ref. 2.1-14). Since none of these sources provides the LD call volume separately for residential and business customers, the data collection and projection had to be made on the basis of total call volume. Tables 16 and 17 of the Statistics of Communications Common Carriers give toll call volume for the Bell System and selected independent telephone companies. The data reported to the FCC

includes unsuccessful call attempts in the total figures without separating them from the successful conversations. The inclusion of unsuccessful call attempts in the total statistics, however, complicates the task of determining call activity. Finally, the FCC statistics after 1974 include WATS calls, a subject which is treated separately in this section. The combination of these factors results in a toll call figure for 1976 which is 67 percent above the figure for completed conversations.

It was, therefore, decided to use the LD call statistics obtained from "The World's Telephones" (Ref. 2.1-10) which list successful conversations only. As shown later in this section, adjustment for network overhead contributed by unsuccessful call attempts is handled separately. The historical growth in the volume of LD conversation is shown in Figure 2.1-5.

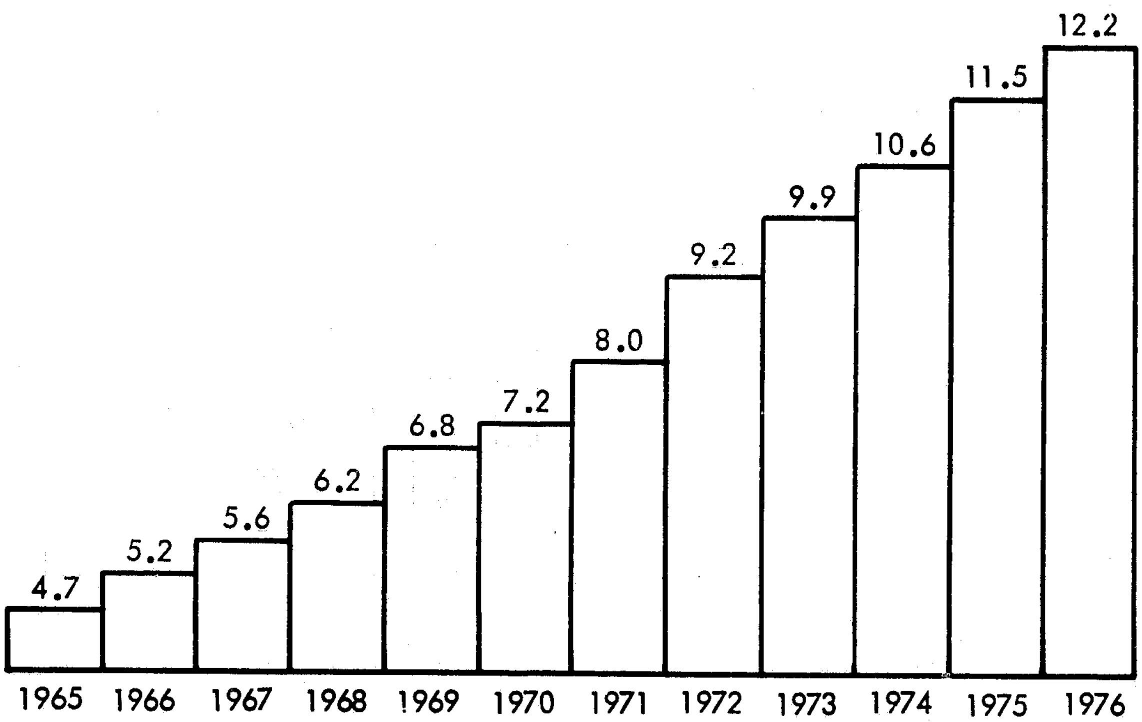

FIGURE 2.1-5. TOLL CALLS COMPLETED 1965 TO 1976 (BILLIONS)

Three methods of predicting the LD conversations volume to the year 2000 were tried. The first method, using linear regression techniques, yielded unreasonably low projected values. This is due to the fact that the historical growth is closer to a constant percentage than a linear volume growth, suggesting use of a log-linear regression method. The log-linear regression yielded projected values that were too high, due to the fact that in the 1970-71 period there was a sudden rise in annual growth rates followed in 1975 by a drop possibly reflecting the 1974 recession. It was therefore decided to construct a growth rate scenario, taking into account the fact that growth is neither linear nor of constant percentage. The growth scenario that was adopted for the projection considered a variety of factors such as gradually decreasing population growth, historical growth rates, the high probability of reduced LD tariffs particularly for the longer distances, introduction of new services, and ultimately, in the last decade, a gradual saturation. The growth rate scenario and the resulting LD conversations per year projections are shown in Figure 2.1-6.

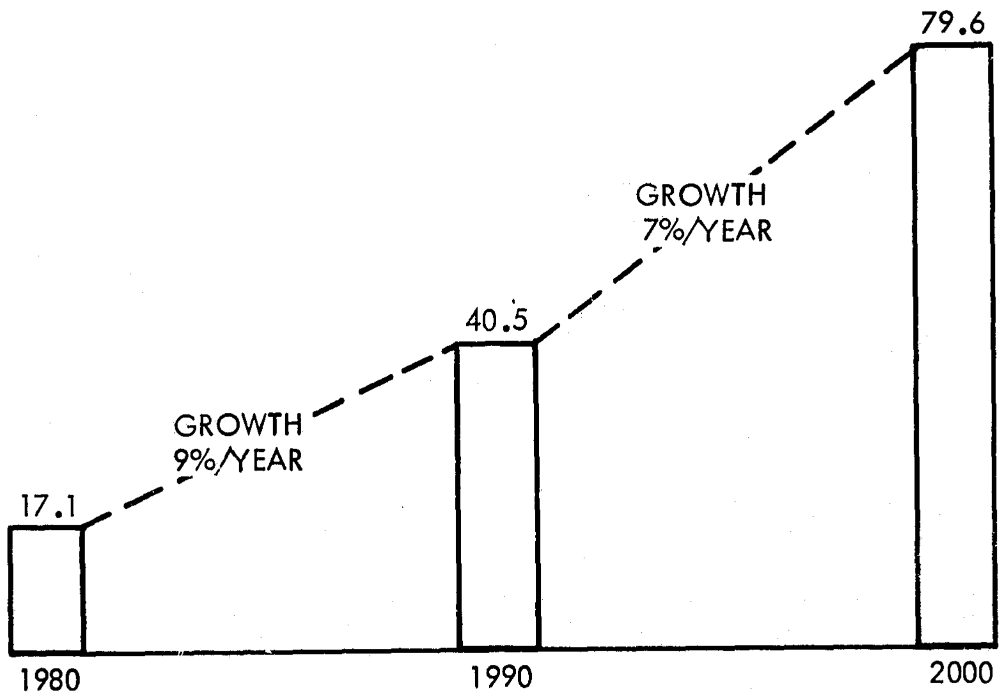

FIGURE 2.1-6. TOLL CALLS COMPLETED - 1980, 1990 AND 2000 (Billions)

Since none of the references examined show the breakdown of the total conversations per year into business and residential, it was necessary to derive the business/residential mix from available data giving business and residential LD toll revenues. MTS toll revenue data for 1987, reported in an IRD study (Ref. 2.1-15) shows an estimated 7.5 billion dollars from residential users and 12.5 billion dollars from business users. This is equivalent to an approximately 38 percent residential and 62 percent business MTS toll revenue mix.

Since an estimate of the residential/business mix in toll conversations based on a toll revenue split must also include a factor accounting for the difference in the average cost of a toll call in each of the two sectors, a toll call profile for both sectors was estimated for the purpose of developing relative call cost comparisons.

For the business sector it was assumed that virtually all MTS toll calls were made between 8 a.m. and 5 p.m. during the business working week, i.e., Monday through Friday, and therefore billed at full cost. For the residential sector, it was assumed that 80 percent of all toll calls are made between 5 p.m. and 11 p.m. at 35 percent discount (Ref. 2.1-16, 2.1-17), ten percent after 11 p.m. and on weekends at 65 percent discount, and ten percent at full rate. This residential call profile yields an average discount of 34 percent, i.e., an average residential toll call cost 66 percent of prime time cost. Factoring the average residential and business call cost ratios into this revenue split results in an estimated business/residential toll conversation split of 52/48 percent.

An examination of the statistics of residential and business main telephones and a projection of these statistics (see paragraph 2.1.2.2) shows that a somewhat higher growth rate for business main telephones compared to residential main telephones can be expected as the year 2000 is approached. If it is assumed that the rate of LD calls per telephone remains approximately constant for both the residential and business sectors, the business share of LD calls will increase slightly at the expense of the residential share due to the gradually widening gap between the growth rates in business and residential main telephones. The growth of residential and business telephones and the resulting shift in the mix of residential and business toll conversations are shown in Table 2.1-7.

In addition, the telephone traffic data should also include the pseudo traffic generated by unsuccessful call attempts since these also occupy time on intertoll trunks and contribute to the sizing of long distance transmission facilities. As mentioned previously, the data compiled in the Common Carrier

TABLE 2.1-7. RESIDENTIAL/BUSINESS MAIN TELEPHONE GROWTH RATE DIFFERENTIAL AND LD CONVERSATIONS MIX - 1978-1980

YEAR	ANNUAL GROWTH (%) - NO. OF MAIN TELEPHONES			RESIDENT/BUS. LD CONVERSATIONS MIX (%)
	RESIDENTIAL	BUSINESS	DIFFERENCE	
1978-1980	3.3	3.6	0.3	48/52
1980-1990	2.8	3.6	0.8	46/54
1990-2000	1.8	3.2	1.4	43/57

Statistics (Ref. 2.1-9) includes successful as well as unsuccessful call attempts, whereas the data compiled in "The World's Telephones" (Ref. 2.1-10) includes successful conversations only. A comparison of these two sets of figures between 1968 and 1974 (the last year in which WATS calls are excluded from the total toll call statistics) shows a gradually increasing trend in the percentage of successful attempts. The average percentage of successful calls for the 1968 through 1974 period is 65.3 percent. A linear regression to the year 2000 indicates that the percentage of successful calls rises gradually from 66.5 percent in 1968 to 66.9 percent in 1980, 68.6 percent in 1990, and finally to 70.4 percent in 2000. It should be noted that a projection on the basis of linear regression does not reflect changes in user behavior, technology improvements and facility growth, all of which may affect the percentage of successful call attempts.

In view of the inherent weakness of this approach to the call completion rate problem, it was decided to investigate other sources. One of these sources (Ref. 2.1-18) quotes a 68 percent completion rate. A more thorough treatment of the problem was found in the Bell System Technical Journal (Ref. 2.1-19). The data on which this article is based was compiled in October 1974 and gives an overall 70.7 percent successful completion rate for all attempts. While it is somewhat higher than indicated from the previously cited references, it is based on a thorough survey. It was decided, therefore, to adopt a 70 percent call completion rate in the computation of toll trunk requirements.

Transmission facilities requirements are a function of the product of the number of conversations and the average holding time per conversation. The values given in the literature for average holding time vary widely, ranging from a commonly used rule-of-thumb of three minutes (a value deemed much too low for current day usage) to nine minutes, a figure given by FSI (Ref. 2.1-20). Additional values obtained informally included three minutes (GTE), 4.6 minutes for intrastate calls and 6.9 minutes for interstate calls (New York Telephone Company).

A paper presented in the report of the Sixth International Teletraffic Congress (Ref. 2.1-21) provides a distribution of average toll message duration vs distance and is shown in Figure 2.1-7.

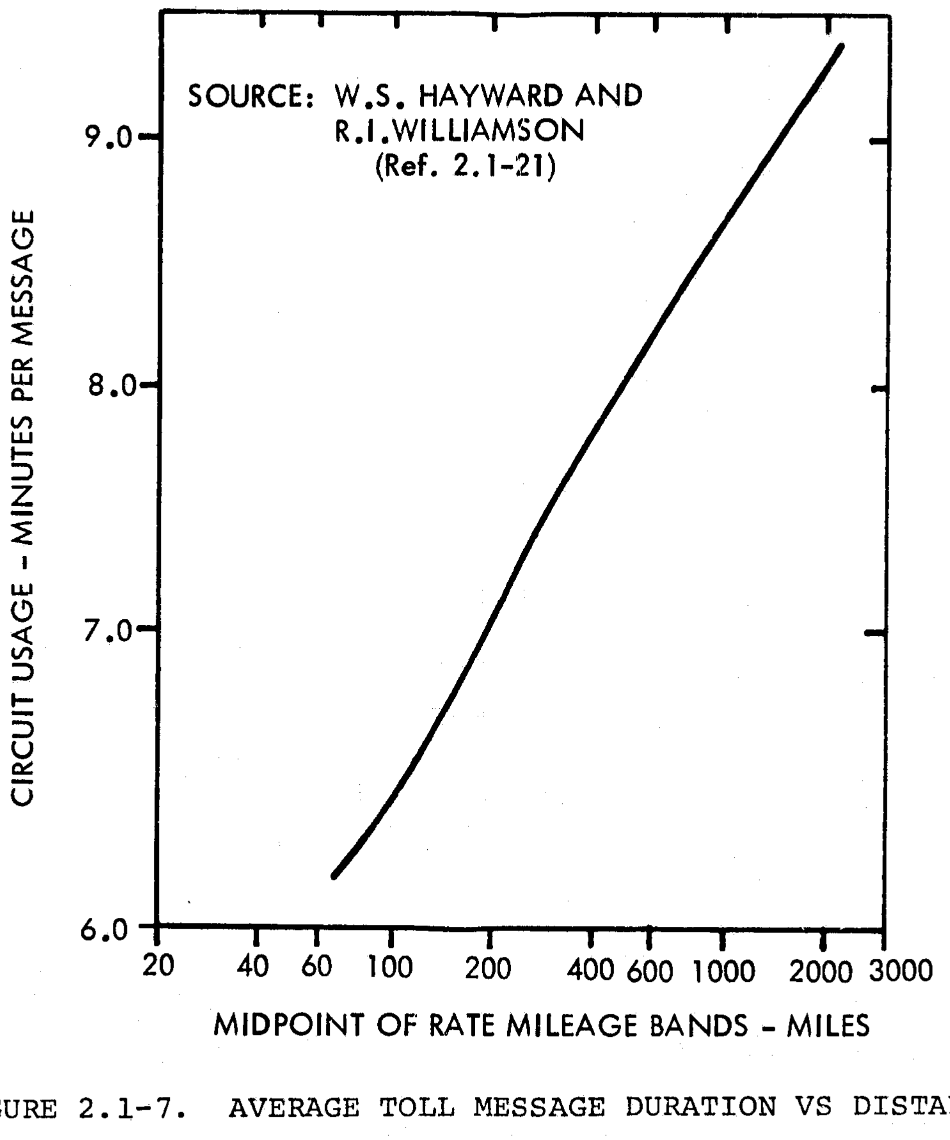

FIGURE 2.1-7. AVERAGE TOLL MESSAGE DURATION VS DISTANCE

This data indicates holding times ranging from approximately six minutes for 60-mile circuits to approximately 9.3 minutes for 2000-mile circuits. This was used in conjunction with distance distribution data on interstate toll call volume (Ref. 2.1-22) to obtain a distance-weighted call duration average. The distance distribution of toll call volume is shown in Figure 2.1-8 and in Table 2.1-8 for 1960, 1965, 1970, and 1975. This table also shows the percentage of total interstate traffic in each of the distance bands and the growth rates of traffic in each of the distance bands as a function of time. The distance distribution data, used in this section only to determine a distance-weighted call duration average, will be treated in greater detail in paragraph 2.1.6.

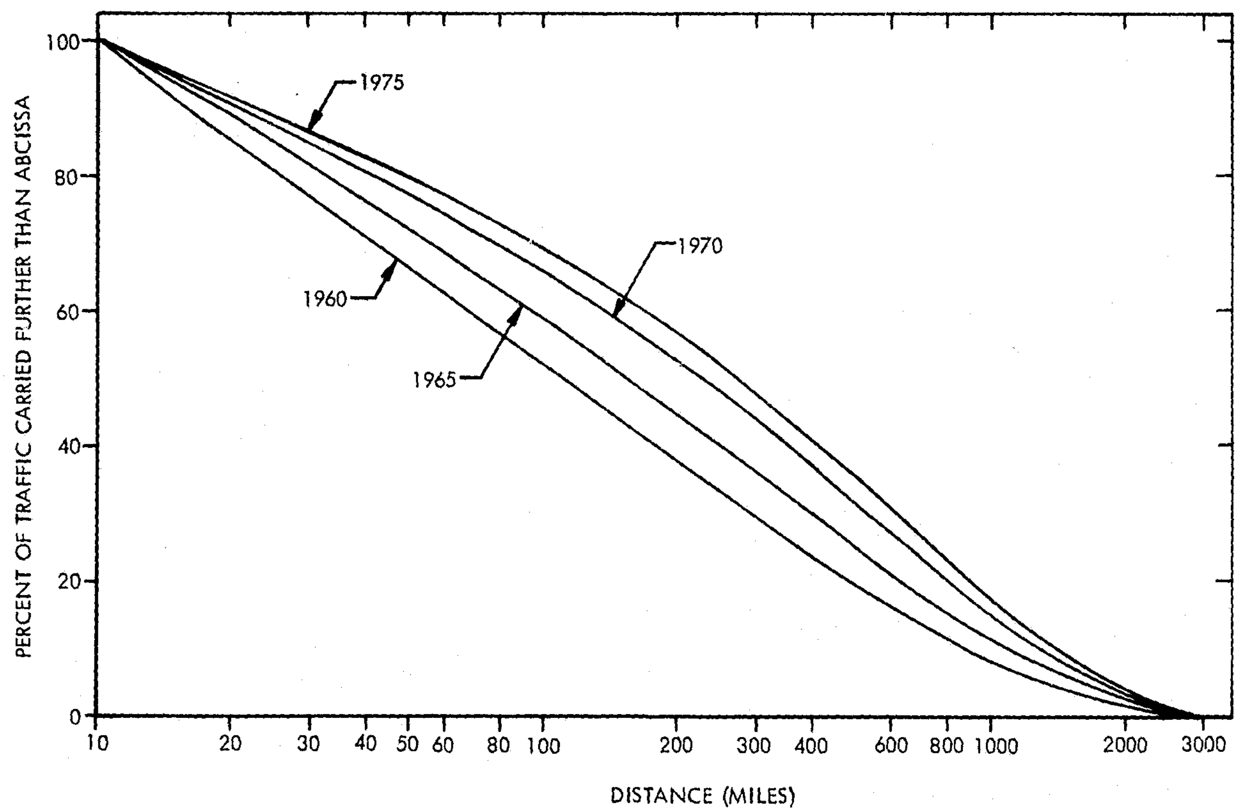

FIGURE 2.1-8. DISTRIBUTION OF INTERSTATE MTS TRAFFIC VS DISTANCE

TABLE 2.1-8. DISTANCE DISTRIBUTION OF INTERSTATE TOLL MESSAGE VOLUME

(a) Total Messages (millions) and Percent of Total Messages by Mileage Bands

Year	0-55 mi.		56-220 mi.		221-506 mi.		507-925 mi.		926-3000 mi.	
	Msgs.	%	Msgs.	%	Msgs.	%	Msgs.	%	Msgs.	%
1960	362	35.7	291	28.7	169	16.7	101	10.0	91	9.0
1965	453	29.7	418	27.4	280	18.4	184	12.1	190	12.5
1970	630	24.0	675	25.7	502	19.2	379	14.5	436	16.6
1975	805	21.1	913	23.9	757	19.8	605	15.8	739	19.4

(b) Average Annual Percent Growth by Distance Bands

Year	0-55 mi.	56-220 mi.	221-506 mi.	507-925 mi.	926-3000 mi.
	%	%	%	%	%
1960-65	4.6	7.5	10.6	12.7	15.9
1965-70	6.8	10.1	12.4	15.5	18.1
1970-75	5.0	6.2	8.6	9.8	11.1

Analysis of the data indicates an average holding time of 7.3 minutes. A comparison of interstate toll message volume as given in Ref. 2.1-22 with total toll conversations indicates that interstate toll calls account for approximately 1/3 and intrastate calls for 2/3 of the total toll calls, a mix verified by consultations with Bell System personnel. If a mean distance for intrastate calls of approximately 75 miles is assumed (6.0 minutes call duration), a weighted call duration average of 6.4 minutes is obtained. In view of the fact that most toll calls are

made within a 50-mile radius of the call originator, a fact reflected by the 4.9-minute average holding time for intrastate calls given by the New York Telephone Company, the 6.4-minute calculated figure was reduced to six minutes. Average holding time for unsuccessful call attempts was obtained from the previously cited January 1978 BSTJ article (Ref. 2.1-19) which quotes 45 seconds.

Two approaches could be taken to calculate the total traffic volume. One is to treat successful and unsuccessful calls individually and apply the average call duration for each separately. The second, and somewhat simpler, method is to calculate a percentage which has to be added (at full holding time) to the successful call volume to account for the approximately 30 percent unsuccessful call attempts. It was the latter approach that was chosen and a quantity called "equivalent LD calls" is henceforth used to indicate the incorporation of the unsuccessful call attempts into the total call volume figures.

The calculation results in an increase of five percent to the successful LD call volume. A projection of equivalent LD calls, including the allowance for unsuccessful call attempts, is shown in Table 2.1-9.

TABLE 2.1-9. TOLL CALL PROJECTIONS, GROWTH RATES AND AVERAGE HOLDING TIMES

Year	Billions of Equivalent* Conversations/Year		Average Holding Time (Sec.)	Annual Compounded Growth (%)	
	Residential	Business		Residential	Business
1980	8.6	9.4	360		
				8.6	9.4
1990	19.6	23.1	375		
				6.3	7.5
2000	36.0	47.8	390		

* Includes adjustment for unsuccessful call attempts

The data presented in Table 2.1-8 and Figure 2.1-8 shows that the average holding time increases as a function of distance and that the percentage of LD calls in the longer distance bands has been consistently increasing over the past 15 years. Since the cost for interstate calls in the longer distance bands have been dropping relative to shorter toll calls, it follows that average holding time will continue to increase. Consequently, average holding times of 375 seconds and 390 seconds were assumed for 1990 and 2000, respectively, and are shown on Table 2.1-9.

2.1.2.4 Peak Factors

In the previous section, equivalent LD calls have been projected on a per year basis. However, terrestrial or satellite transmission facilities must be sized not on the basis of yearly traffic volume but on the basis of the maximum flow rate of traffic the facility must pass for a specific period of time. Telephone engineers define this to be the busy hour of the day.

Of the three traffic components defined in subsection 2.1 (MTS, WATS, and Private Line), the latter two are employed by the business sector and therefore follow the general business day usage profile. MTS, however, is divisible into two components: Residential and Business. Since neither component is negligible and both have different hourly traffic distributions, the peak hour residential and business MTS traffic had to be calculated separately so that the worst case situation could be determined. To do this, the peak hour traffic of one component is added to that traffic offered to the network at the same time by the other component.

While a considerable amount of data exists concerning the daily traffic volume profile in local switching offices, this information is not readily available for LD traffic separately. A breakdown of LD traffic into business and residential components is also not available. The separate traffic profiles, therefore, had to be developed based on composite traffic profiles published in the literature (Ref. 2.1-19, -23, -24).

Nearly all residential traffic occurs in the 16 hours from 8 a.m. to midnight. The peak hours occur between 7 p.m. and 11 p.m. partly because tariffs are lower at those times and partly because that is the period during which most members of the household are at home. For these reasons, approximately 80 percent of the day's traffic is carried during those four hours. Thus, the percentage of daily traffic carried during the peak hour (the busy hour equivalent) is 20 percent.

The parameter commonly used in traffic computations is the peaking factor (PF) which is defined as the ratio of the traffic carried in the peak hour to the day's traffic averaged over 24 hours. A busy hour equivalent of 20 percent, therefore, corresponds to a PF of 4.8 for the residential sector. The remaining 20 percent of the non-busy hour traffic is nearly all in the 12 hours from 8 a.m. to 7 p.m. and 11 p.m. to midnight, yielding 1.67 percent of the day's traffic for each of the 12 non-busy hours.

In a similar manner, a busy hour equivalent of 11.67 percent (corresponding to a PF of 2.8) was calculated for the business sector of the MTS traffic. The business peak hours are well documented in the literature (Ref. 2.1-19, -23, -24) as being from 10 a.m. to noon and from 1 p.m. to 3 p.m. The traffic in the non-peak hours is, therefore, [100 -(4 x 11.67)]% = 53.32% of the day's traffic. This corresponds to 6.67 percent of the day's business traffic in each of the eight off-peak hours since the remaining 12 hours of the day carry an insignificant amount of business traffic.

The percent of the daily MTS business and residential traffic carried in each of the respective peak hours is summarized in Table 2.1-10.

TABLE 2.1.10 RESIDENTIAL AND BUSINESS TRAFFIC COMPONENTS AS A PERCENTAGE OF DAILY TRAFFIC DURING THE RESIDENTIAL PEAK HOUR AND DURING THE BUSINESS PEAK HOUR

	PERCENT OF DAILY MTS TRAFFIC DURING:	
	Residential Peak Hr.	Business Peak Hour
Residential MTS	20.00	1.67
Business MTS	6.67	11.67

2.1.2.5 Peak Hour Traffic

Calculation of the peak hour MTS traffic requires determining whether the MTS traffic in the business peak hour or in the residential peak hour is larger. This establishes the controlling peak hour and, as a result, requires the addition of the business traffic component to the residential traffic

component at each of the peak hours to determine the dominant one. The calculation proceeds as follows.

The yearly residential and business traffic shown in Table 2.1-9 is converted to daily traffic by dividing by 365 days/year for residential traffic, and by 250 days/year for business traffic. The daily traffic is then multiplied by the percentages given in Table 2.1-10 to obtain the respective traffic components in Table 2.1-11.

TABLE 2.1-11. RESIDENTIAL AND BUSINESS MTS TRAFFIC COMPONENTS
(Millions of Equivalent Calls)

Traffic During Residential Peak Hour

Year	Residential Traffic	+	Business Traffic	=	Total Traffic
1980	4.73	+	2.50	=	7.23
1990	10.74	+	6.15	=	16.89
2000	19.74	+	12.76	=	32.50

Traffic During Business Peak Hour

Year	Residential Traffic	+	Business Traffic	=	Total Traffic
1980	.40	+	4.37	=	4.77
1990	.90	+	10.76	=	11.66
2000	1.64	+	22.33	=	23.98

Note: Equivalent calls include adjustment factor for unsuccessful call attempts.

As indicated in Table 2.1-11, MTS traffic during the Residential Peak Hour is higher than that in the Business Peak Hour. However, when WATS, Private Line, Data and Video traffic is added to the MTS traffic, this situation reverses and the Business Peak Hour will be found to be the controlling one.

2.1.3 WIDE AREA TELEPHONE SERVICE (WATS)

WATS is a telephone service which permits users to make long distance calls at a reduced rate. The service is offered as an outbound service (Out-WATS), permitting a discounted call to be made from the subscriber's offices, or as an inbound service (In-WATS), permitting the user to be called at no charge to the calling party.

Technically, WATS is a modified form of MTS service in which the user enters the long distance network by means of a WATS access line. In the case of Out-WATS, the user dials a specific number, generally varying from one to three digits, which seizes the WATS access line from his PBX and connects him to the MTS toll switch, usually a Class 4 office. From that point on, the call is treated in the same manner as an MTS call except for the billing. In the case of In-WATS, the calling user dials the access code 800 to use the service. When WATS access lines are busy, the caller hears a busy tone and has a choice of either waiting until the access line is free or completing the call via the Direct Distance Dial (DDD) network providing conventional MTS service.

2.1.3.1 WATS Call Projections

The number of WATS messages handled by the Bell System from 1974 through 1978 was obtained from the AT&T 1978 Annual Report (Ref. 2.1-25) and is shown in Table 2.1-12 along with the resultant growth rate. FCC statistics (Ref. 2.1-9) show that total WATS revenue for 1977 was 2.328 billion dollars and independent telephone carrier statistics (Ref. 2.1-14) indicate that WATS revenue for these carriers was 126 million dollars in the same year. Assuming this ratio does not change significantly, multiplying the Bell System WATS messages per year by a factor of 1.054 gives the total WATS messages per year for the U.S. telephone industry.

Since, from the network point of view, WATS is indistinguishable from MTS, the same multiplying factor of approximately five percent used in MTS to account for unsuccessful call attempts, was also used for WATS. The last column of Table 2.1-12 shows the equivalent WATS calls incorporating this factor.

In view of the current regulatory climate encouraging competition to WATS from the specialized common carriers (SCCs) and other common carriers (OCCs), and the possibility of resulting tariff changes, a considerably more modest growth in WATS traffic was assumed. The projected growth of WATS from 1978 to the year 2000 is shown in Table 2.1-13.

TABLE 2.1-12. WATS MESSAGE VOLUME AND GROWTH RATES

Year	WATS Messages/Year (Millions) Bell System	Total	Equivalent[1]	Equiv. WATS Messages/Day (Thousands)	Annual Growth Percent[2]
1974	1,605	1,692	1,783	7,131	
1975	1,942	2,047	2,157	8,627	21.0
1976	2,451	2,583	2,721	10,886	26.2
1977	3,046	3,211	3,383	13,532	24.3
1978	3,631	3,827	4,032	16,128	19.2

1. Includes adjustment for unsuccessful call attempts.
2. Growth since previous year.

TABLE 2.1-13. WATS MESSAGE VOLUME, GROWTH RATE, AND AVERAGE HOLDING TIME PROJECTIONS

Year	Equiv. WATS Messages/Yr. (Millions)	Annual Growth Rate-%	Average Holding Times (Seconds) During: Bus.Pk. Hr.	Res.Pk.Hr.
1980	5,519		396	480
		8.0		
1990	11,915		413	490
		4.0		
2000	17,638		429	500

2.1.3.2 Peak Factors

The component of WATS traffic attributable to the residential sector is negligible. In the business sector, the forces that affect the call distribution for WATS are essentially the same as those that affect Business MTS and, therefore, the same peaking factor was used.

2.1.3.3 Peak Hour Traffic

In computing the WATS peak hour traffic, the same methods described in 2.1.2.4 were used. However, average holding times for WATS calls made during the business peak hour were increased by ten percent to account for longer conversation lengths due to the decreased costs in comparison to MTS service. Average WATS call duration in the residential peak hours was further increased to 480, 490, and 500 seconds for 1980, 1990, and 2000, respectively, because WATS lines are more accessible in the late hours of the business day and therefore are frequently used for longer hold time such as facsimile transmission, applications requiring computer access, etc.

The projected WATS traffic during the business and residential peak hours is given in Table 2.1-14.

TABLE 2.1-14. WATS MESSAGES - PEAK HOUR PROJECTIONS (Millions)

Year	During Business Peak Hour	During Residential Peak Hour (7-8 p.m.)
1980	2.58	1.47
1990	5.56	3.18
2000	8.23	4.71

Note: Messages include adjustment for unsuccessful call attempts.

2.1.4 PRIVATE LINES

Private Lines are dedicated transmission facilities leased from franchised telephone companies or from specialized and other (e.g. domestic satellite) common carriers. These lines are generally independent from the MTS network except where they are interconnected with the local Class 5 switching offices for distribution via the local switched network.

Since private lines are generally leased on a full-time basis and the traffic over them is not measured by the leasing company, traffic statistics are not generally available. Similarly, very little comprehensive information concerning the number of private lines in use is available. The best detailed data is in terms of revenue and is available in the FCC Statistics of Communications Common Carriers (Ref. 2.1-9) for historical data, and a number of other services for projections, including References 2.1-15, -26 and -27.

The various revenue forecasts were compared after adjustment to current dollars. The number of private lines was then calculated on the basis of a weighted average cost of $700 per line per month for Bell System, SCC, and OCC private lines.

The results of this analysis, including calculated revenue shares of the telephone carriers and the SCCs and OCCs are shown in Table 2.1-15. None of the documents examined, however, provide comprehensive revenue forecasts beyond 1988. Therefore, Table 2.1-15 carries revenue data to that year only. Revenue shares are shown for 1990 and 2000 based on extrapolation of the 1978 to 1988 revenue share data. This extrapolation takes into account the rapid growth of the SCCs and OCCs as well as a current and projected regulatory climate (deregulation) which encourages that growth relative to that of conventional telephone carriers.

Based on this analysis of private line revenues, the growth of the number of private lines is anticipated to be 10 percent in the decade from 1980 to 1990 and nine percent in the decade from 1990 to 2000. The resultant number of duplex private lines is shown in the last line of Table 2.1-15.

TABLE 2.1-15. PRIVATE LINE REVENUE, CIRCUIT AND GROWTH RATE PROJECTIONS*

	1978	1980	1983	1988	1990	2000
Conventional Common Carriers (Telcos)						
Revenue (Millions of Current $)	1702	1999	2435	3131		
% of P.L.Market	93	86	80	69	66	55
SCCs and OCCs						
Revenue (Millions of Current $)	135	317	614	1402		
% of P.L.Market	7	14	20	31	34	45
Total Voice P.L.						
Revenue (Millions of Current $	1837	2316	3049	4533		
Growth Rate (Percent/Yr)	12.5			10.0	9.0	
Thousands of Duplex Lines	219	277	369	594	718	1700

*Includes both interstate and intrastate lines with the exclusion of local lines.

2.1.5 VOICE EQUIVALENT CIRCUIT PROJECTIONS

In this section the peak-hour projections of MTS and WATS traffic are converted into voice equivalent circuits considering the peaking factors and average holding times derived in Sections 2.1.2 and 2.1.3. These projections are then added to the private line circuit projections derived in Section 2.1.4 to obtain a total estimate of voice equivalent circuits for the three voice service categories.

2.1.5.1 MTS

The method generally accepted in the telephone industry to compute the number of circuits required to carry a given volume of traffic is based on statistical queuing formulas developed by A. K. Erlang. Circuit requirements depend on the product of the number of conversations and the average holding time per conversation, the grade of service required, and the number of available servers.

The grade of service, usually expressed as a decimal number less than 1.0, represents the probable percentage of calls lost or delayed during the period considered. A commonly accepted grade of service is 0.01, indicating that one call out of 100 is lost or delayed. Assuming that some of these losses are due to inadequate facilities in the local distribution network, i.e., between the user and the nearest toll (Class 4) office, a grade of service of .003 allocated to the intertoll portion of the network is a conservative estimate. The number of servers represents the trunk group size, i.e., the number of trunks available for handling traffic. In queuing situations, the service efficiency increases with the number of servers available, i.e., an increase in the number of servers to meet increasing traffic volume results in better "packing efficiency".

Once trunk group sizes of 100 are exceeded, the "packing efficiency" improves very slowly with further increases in trunk group size. For example, given an intertoll trunk grade of service of .003, a 78.9% efficiency is achieved with trunk group sizes of 100 and 91.7% with trunk group sizes of 500. Increasing trunk group size from 500 to 1500 increases the efficiency by only 4.2%. Since trunk group sizes in the majority of significant toll offices are generally large, a trunk group size of 500 represents a reasonable compromise reflecting as close as possible a realistic nationwide network.

A trunk group of 500 trunks can support a traffic intensity of approximately 460 Erlangs with a grade of service of .003. This can be derived by the use of the standard Erlang tables

such as those in Reference 2.1-28. Equivalent circuits can thus be calculated by use of the call projections in Table 2.1-11 and the average holding times in Table 2.1-9. The results of the calculations are shown in Table 2.1-16.

TABLE 2.1-16. MTS EQUIVALENT VOICE CIRCUIT PROJECTIONS

Year	Duplex Equivalent Voice Circuit Requirements (Millions) Based On:	
	Residential Peak Hour Traffic	Business Peak Hour Traffic
1980	0.79	0.52
1990	1.92	1.33
2000	3.84	2.83

2.1.5.2 WATS

The equivalent voice circuit projections for WATS were computed using the same methods described in the above paragraph. The results for the business and residential peak hours are shown in Table 2.1-17.

TABLE 2.1-17. WATS EQUIVALENT VOICE CIRCUIT PROJECTIONS

Year	Duplex Equivalent Voice Circuit Requirements (Millions) Based On:	
	Residential Peak Hour Traffic	Business Peak Hour Traffic
1980	0.21	0.31
1990	0.47	0.70
2000	0.71	1.07

2.1.5.3 Synthesis

To obtain the total equivalent voice circuit requirements for the three sectors comprising the voice services, the calculated projections shown in paragraph 2.1.5.1 for MTS and paragraph 2.1.5.2 for WATS are added to the private line projections derived in paragraph 2.1.4. The results are shown in Table 2.1-18.

TABLE 2.1-18. VOICE SERVICE PROJECTIONS FOR ALL LONG DISTANCE CALLS - MILLIONS OF DUPLEX VOICE EQUIVALENT CIRCUITS

Controlling Peak Hour	Year	MTS	WATS	Private Line	Total
Residential	1980	0.79	0.21	0.28	1.28
	1990	1.92	0.47	0.72	3.11
	2000	3.84	0.71	1.70	6.25
Business	1980	0.52	0.31	0.28	1.11
	1990	1.33	0.70	0.72	2.75
	2000	2.83	1.07	1.70	5.60

The table shows that the combined total of all voice services results in a slight dominance by the Residential peak hour, when all toll traffic is considered. Moreover, the application of the distance factors to the total toll traffic causes the voice traffic in the residential and business peak hours to be essentially equal. (See Section 2.1-6 and Table 2.1-20.) When combined with Video and Data Traffic, however, the Business peak hour becomes controlling for all traffic.

2.1.6 DISTANCE DISTRIBUTION

The traffic values and equivalent circuits calculated above represent the total LD traffic for the continental United States independent of distance carried. Satellite candidate traffic, however, assumes a distance between end points of at least 200 miles. This requires the determination of the distribution of LD traffic with respect to distance. Two factors were used in making this determination.

The first of these is the distance distribution of interstate toll message volume (Ref. 2.1-8), based on data submitted by AT&T to the FCC as part of Docket 18128. The second factor involves the mix of interstate and intrastate traffic, estimated from the statistics of Communications Common Carriers (Ref. 2.1-9). The latter results in an approximate mix of one-third interstate and two-thirds intrastate.

The data from Table 2.1-8 was plotted as a cumulative distribution in Figure 2.1-8 at five year intervals from 1960 to 1975. For the year 1975 approximately 55 percent of all interstate message volume travels farther than 200 miles. The data from Table 2.1-8 shows that the percentage of interstate traffic in the distance bands above 200 miles increases with time. This increase is illustrated in Figure 2.1-9. The Figure shows that for 1980, 1990 and 2000, the percentage of the traffic travelling greater than 200 miles is 57 percent, 58.5 percent, and 59 percent, respectively.

For intrastate traffic, the interstate distance distribution was scaled down according to average state geography. That is, the average maximum intrastate distance corresponds to approximately 300 miles for the larger states. On this basis, more than 60 percent of all intrastate traffic falls within a 50 mile radius and approximately two percent in the 200 to 300 mile range for 1980 to 2000.

The above distance distributions are then applied to the three sectors of the voice services to adjust the total LD traffic projections for greater than 200 miles. In the case of WATS, however, where the intrastate component is negligible, the interstate percentages for distances greater than 200 miles are applied to the entire WATS traffic.

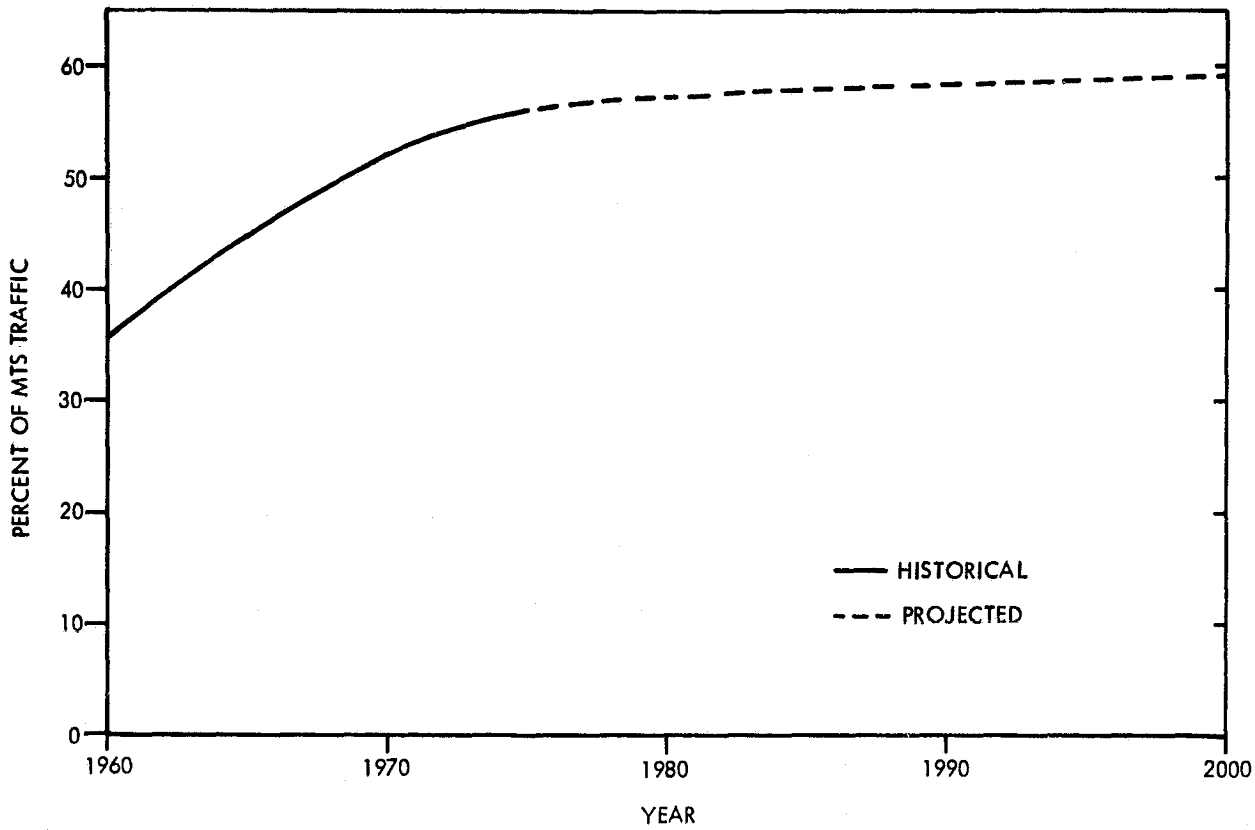

FIGURE 2.1-9. PERCENT OF MTS INTERSTATE TRAFFIC CARRIED FARTHER THAN 200 MILES VS. YEAR

The resulting distance factors and their application to the total equivalent circuits projections are shown in Tables 2.1-19 and 2.1-20, respectively. Table 2.1-20 shows that the application of the distance factors eliminates the dominance of the residential peak hour when all toll traffic is considered (Table 2.1-18) and causes the traffic carried over distances greater than 200 miles to be balanced in the two peak periods. This is due to the fact that WATS traffic is primarily interstate. The result is a clear dominance of the business peak hour for all traffic (voice, data and video) carried for distances greater than 200 miles.

TABLE 2.1-19. DISTANCE FACTORS
(Portion of Total Toll Traffic ≥ 200 Miles)

Year	Service	Interstate Traffic Share	x	Amount >200 Miles	+	Intrastate Traffic Share	x	Amount >200 Miles	=	Distance Factor
1980	MTS & PL	1/3		0.570		2/3		0.02		0.203
1990	"	1/3		0.585		2/3		0.02		0.208
2000	"	1/3		0.590		2/3		0.02		0.210
1980	WATS	1		0.570						.570
1990	"	1		0.585						.585
2000	"	1		0.590						.590

TABLE 2.1-20. PEAK HOUR VOICE SERVICE PROJECTIONS
MILLIONS OF DUPLEX VOICE EQUIVALENT CIRCUITS
(Greater than 200 Miles)

Controlling Peak Hour	Year	MTS	WATS	Private Line	Total
RESIDENTIAL	1980	0.16	0.12	0.06	0.34
	1990	0.40	0.28	0.15	0.83
	2000	0.81	0.42	0.36	1.59
BUSINESS	1980	0.11	0.18	0.06	0.35
	1990	0.28	0.41	0.15	0.84
	2000	0.59	0.63	0.36	1.58

2.1.7 SUMMARY OF VOICE TRAFFIC DEMAND

The previous subsections developed the voice traffic demand projections for the voice service categories of Message Toll Service (MTS), Wide Area Telephone Service (WATS), and Private Line Service. These are now summarized in a form which is used in subsequent sections to develop the potential traffic requirements suitable for transmission via Ka band satellites. Specifically, the values shown in Table 2.1-21 are used in Subsection 2.4 to derive the traffic demand in digital terms for calculation of capacity on a digital satellite transponder. The quantities in each category given in Table 2.1-21 represent traffic travelling greater than 200 miles.

TABLE 2.1-21. VOICE TRAFFIC PROJECTIONS
(Greater than 200 Miles)

Voice Service Category	1980	1990	2000
MTS Residential (billion call-sec.)	634	1540	2950
MTS Business (billion call-sec.)	686	1800	3920
WATS (billion call-sec.)	1250	2880	4470
Private Lines (thousands)*	57	150	357

*Private lines are defined as standard 4 KHz duplex voice lines.

The summary values shown in Table 2.1-21 are obtained from the data given in Tables 2.1-9, 2.1-13, and 2.1-15 for MTS, WATS and Private Lines, respectively, after applying the distance factors for each voice service shown in Table 2.1-19. The demand shown in the earlier tables, when multiplied by the distance factors, results in the figures for traffic greater than 200 miles as shown in Table 2.1-21.

2.2 VIDEO SERVICES DEMAND

The ability of satellite systems to provide large numbers of wide-band communications channels is expected to stimulate demand for video services. Substantial growth in demand is anticipated for established video services such as broadcast TV (network and CATV), but even greater growth is expected in newer applications serving education, medicine and video teleconferencing.

2.2.1 CATEGORIES OF VIDEO SERVICES

To carry out the analysis and projection of demand, video services were segmented into five categories. While there are some relatively short range uses of video, these do not present attractive targets for satellite transmission. The demand projections discussed in the following pages, therefore, include only those video transmissions that travel nominally 200 miles or more.

(a) Network TV - Composed of commercial and non-commercial broadcasting systems delivering regular full-time nationwide programming through affiliated stations.

(b) CATV - Comprising program originators, other than networks, delivering TV broadcasting on a part-time (in some instances), ad hoc, regional or national basis.

(c) Videoconferencing - Two-way, real-time, video communications between two or more points.

(d) Educational Video - The utilization of wideband video channels (usually in one direction only) to deliver educational programs, with or without two-way audio interactive capability.

(e) Health and Public Affairs - Includes video support of applications such as Telemedicine, Courts, Public Forums, Disaster Relief, and Law Enforcement.

These segments include well-established categories (TV Networks), newer rapidly growing categories (CATV Program Originators), and currently experimental applications of wideband transmission systems (videoconferencing, educational, etc.). The lack of a long term historical experience in many of the video categories dictated that the investigation be supported by the opinions of a large number of users, equipment, and service providers and analysts working in the various video service categories. Table 2.2-1 is an alphabetical listing of the organizations that were contacted in arriving at the forecasts contained in this report.

TABLE 2.2-1. ORGANIZATIONS CONTACTED FOR VIDEO SERVICES DATA

1. American Broadcasting Company
2. AT&T Long Lines
3. AT&T Picturephone Meeting Serv.
4. American Satellite Corporation
5. Appalachian Educ. Television
6. Appalachian Project
7. Arthur D. Little
8. Assoc. of Independent TV Sta.
9. Bell Canada
10. Bell Laboratories
11. British Post Office
12. CATV Association
13. Columbia Broadcasting Company
14. Communications News
15. Corp. for Public Broadcasting
16. Dayton Research Institute
17. Dow Chemical Co.
18. Educom
19. Federal Aviation Administration
20. Federal Communications Comm.
21. Frost & Sullivan
22. Future Systems Inc.
23. General Electric
24. General Telephone & Electronics
25. George Washington University
26. Goldman, Sachs & Co.
27. Illinois Institute of Technology
28. Institute for the Future
29. International Business Machines
30. Infomedia Inc.
31. International Paper
32. Internat'l. Resource Devel. Inc.
33. International Tel. & Tel.
34. J. Walter Thompson
35. Joint Council on Education
36. Media Based Contin. Educ. Assoc.
37. Metropolitan Regional Council
38. Mitre Corporation
39. Montgomery Ward
40. NASA
41. Nat'l. Assoc. of Broadcasters
42. Nat'l. Broadcasting Corp.
43. Nat'l. Institute of Educ.
44. Nat'l. Telecomm. & Info. Admin.
45. N.Y.U. Alternate Media Center
46. New York Telephone Company
47. Nippon Electric Corp.
48. Penn State University
49. Public Broadcasting System
50. Public Serv. Satellite Consort.
51. Quantum Science Corporation
52. Rand Corporation
53. RCA Americom
54. Rockwell International
55. R.W. Hough & Associates
56. Satellite Business Systems
57. Satellite Comm. Magazine
58. Stanford Research Institute
59. State of Georgia
60. State of Illinois
61. Stone & Webster
62. Telephone Engineer & Mgt.
63. Telephony
64. Teleprompter
65. Television Factbook
66. Texaco
67. University of Kentucky
68. University of Illinois
69. University of Mid America
70. University of Southern Calif.
71. University of Wisconsin
72. Viacom International
73. Warner Communications
74. Western Electric
75. Western Union
76. Westinghouse
77. Xerox
78. Young and Rubicam

2.2.2 NETWORK TV

The television age began in the U.S. in 1946 with broadcasting by six local stations to a few thousand receivers. In 1947 and 1948, 137,000 and 835,000 sets were sold respectively. By year end 1948, TV sets in use in the United States reached almost one million. A network system began to evolve in 1948 with four networks (the current three plus Du Mont) distributing programming through 10 stations. The number of TV sets in use exploded from just under a million at the beginning of 1949 to about 130 million by 1977, with household penetration rising from three percent to 97 percent over the same 28-year period (see Table 2.2-2). During the same interval, the number of stations on the air grew to 972 (see Table 2.2-3). However, from the mid-sixties on, most of the growth has occurred in the UHF and VHF educational TV sectors while the number of VHF commercial stations has remained fairly stable.

Despite these explosive growth trends, the number of commercial TV networks has remained constant at three since September 15, 1955, when Du Mont ceased operations. This situation is expected to continue through the 1980s. The networks themselves, and most independent experts (see, for example, Ref. 2.2-1), tend to discount the possibility of a fourth commercial network coming into being in the next decade and, while FCC Chairman Charles Ferris indicated his expectation that five additional networks might be assembled from the largely unaffiliated UHF stations (Wall Street Journal 1/5/79), it is likely that this will be largely pertinent to CATV rather than to the Network TV category.

The slowness of new TV networks in emerging is not due to a lack of market opportunity. The growth of revenues for the TV industry has been tremendous, rising from $14.9 million loss in 1948 to $150.2 million pre-tax profits in 1955, $414.6 million pre-tax profits in 1964, and $1,250.2 million pre-tax profits in 1976. In addition, TV has captured a significant portion of total advertising expenditures reaching 20 percent of the total in 1976 (Ref.2.2-2).

With the cost of TV advertising exceeding $100,000 a minute on highly rated shows, the stimulus for the creation of new networks is strong, yet no new networks have been created in almost 25 years. This appears to be due primarily to the high (and rising) cost of programming. Salaries for top performers, and enormous overhead and production costs, require that a network spend many millions of dollars in the creation of shows which often have a high mortality rate.

TABLE 2.2-2. TELEVISION SETS IN USE (THOUSANDS AT YEAR END)

Year	Monochrome TV	Color	Total
1946	5	--	5
1947	140	--	140
1948	975	--	975
1949	3,595	--	3,595
1950	9,700	--	9,700
1951	15,510	--	15,510
1952	21,410	--	21,410
1953	26,920	--	26,920
1954	32,745	5	32,750
1955	37,435	25	37,460
1956	42,405	75	42,480
1957	46,640	140	46,780
1958	49,700	200	49,900
1959	53,030	300	53,330
1960	55,655	425	56,080
1961	58,165	575	58,740
1962	60,465	915	61,380
1963	62,725	1,585	64,310
1964	64,490	2,860	67,350
1965	65,240	5,350	70,590
1966	65,130	9,340	74,470
1967	64,860	14,390	79,250
1968	63,640	19,920	83,560
1969	62,740	25,280	88,020
1970	62,380	30,000	92,380
1971	61,100	35,800	96,900
1972	72,790	42,500	105,290
1973	62,930	49,800	112,730
1974	65,590	54,560	120,150
1975	66,600	58,460	125,060
1976	66,400	63,000	129,400

Source: Television Factbook 1978 Edition

TABLE 2.2-3. COMMERCIAL AND EDUCATIONAL TELEVISION STATIONS ON AIR, 1946-1977 (AS OF JAN. 1 FOR EACH YEAR)

Year	VHF Coml.	VHF ETV	Total VHF	UHF Coml.	UHF ETV	Total UHF	Total Coml.	Total ETV	Grand Total
1946			6			--			6
1947			12			--			12
1948			16			--			16
1949			51			--			51
1950			98			--			98
1951			107			--			107
1952			108			--			108
1953			120			6			126
1954	233	1	234	121	1	122	354	2	356
1955	297	8	305	114	3	117	411	11	422
1956	344	13	357	97	5	102	441	18	459
1957	381	17	398	90	6	96	471	23	494
1958	411	22	433	84	6	90	495	28	523
1959	433	28	461	77	7	84	510	35	545
1960	440	34	474	75	10	85	515	44	559
1961	451	37	488	76	15	91	527	52	579
1962	458	43	501	83	19	102	541	62	603
1963	466	46	512	91	22	113	557	68	625
1964	476	53	529	88	32	120	564	85	649
1965	481	58	539	88	41	129	569	99	668
1966	486	65	551	99	49	148	585	114	699
1967	492	71	563	118	56	174	610	126	737
1968	499	75	574	136	75	211	635	150	785
1969	499	78	577	163	97	260	662	175	837
1970	501	80	581	176	105	281	677	185	862
1971	503	86	589	179	113	292	682	199	881
1972	508	90	598	185	123	308	693	213	906
1973	510	93	603	187	137	324	697	230	927
1974	513	92	605	184	149	333	697	241	938
1975	514	95	609	192	152	344	706	247	953
1976	511	97	608	190	162	352	701	259	960
1977	515	101	616	196	160	356	711	261	972

Source: Television Factbook 1978 Edition

Among shows that do succeed in the fiercely competitive rating wars, the cost of producing a single program is about $250,000 and can easily exceed $500,000. The high costs of programming introduce investment requirements that prove to be blocks for many contemplated new commercial networks. Thus, the attraction of advertising dollars is negated by the heavy investment required and only the largest entertainment companies are likely to be successful in establishing new TV networks. For the purposes of forecasting video communications demand, therefore, this study has assumed that the present population of three commercial TV networks will continue until 1990 at which point the possible emergence of a fourth commercial network is foreseen.

The sole non-commercial network, PBS, contributes a smaller but significant component of network video traffic demand. PBS is making extensive use of satellite communications at a reported great savings in cost (PBS president Henry Loomis, TV Guide 12/9/78). The network currently leases three video channels from Western Union and plans to add a fourth channel in 1980. Projections for the foreseeable future (Carnegie Commission, Time Magazine 2/12/79) indicate that four channels should be sufficient to meet evolving requirements.

Estimates for Network TV channel demand for 1978, 1980, and 1990 and 2000 are presented in Table 2.2-4.

TABLE 2.2-4. NETWORK TV - CHANNEL DEMAND FORECAST (VIDEO CHANNELS)(1)

	1978	1980	1990	2000
Commercial Networks(2)	6	6	8	12
Non-Commercial Networks(3)	3	4	4	4
Total Full Time Demand	9	10	12	16
Additional Channels for Occasional Demand(4)	15	15	18	19

(1) Subject to bandwidth compression as per Section 2.4

(2) 3 Networks using 2 time zone transmissions '78 and '80
4 Networks using 2 time zone transmissions 1990
4 Networks using 3 time zone transmissions 2000

(3) PBS requirements

(4) Regional sports events plus news feeds

These estimates are predicated on the previous discussions and reflect inputs from AT&T Long Lines, the TV Networks, and other experts in the field.

The entries in Table 2.2-4 for commercial networks show the requirements of the three existing networks through the 1980s. Separate transmissions are needed to accommodate each of two time zones (the Eastern and Central regions and the Mountain and Western regions), so that the three networks require a total of six video channels. The emergence of a fourth commercial network by the year 1990 raises this total to eight video channels. By the year 2000 it is postulated that the added flexibility of three time zone program dissemination will be introduced so that the four commercial networks expected to be operating at that time will require a total of 12 channels.

The projections shown in Table 2.2-4 also show the previously discussed near term growth of non-commercial TV to four video channels and present the total full-time video channels needed to support commercial and non-commercial Network TV.

In addition to the full-time demand discussed above, there are occasional heavy demands to accommodate regional sports and special news events. Estimates for these requirements are also presented in Table 2.2-4, but since these peak needs generally occur at a time (typically Sunday afternoons) in which a large amount of spare capacity (normally devoted to business traffic) is available, the peak demand is not important in determining overall satellite requirements. Since these occasional channels are used only briefly, their effect is negligible in terms of both peak and overall demand and they are therefore not considered in the remainder of this report.

2.2.3 CATV

In 1949, three years after commercial television was introduced, CATV was born. The first CATV systems were built to provide transmission to reception-poor areas by using a large antenna to pick up the signal and relaying the signal in to the reception-poor area on a wideband terrestrial system. The early growth of CATV was moderate. However, when CATV operators began offering the added value of diverse programming, both the number of subscribers and the number of systems increased sharply (Fig. 2.2-1). As CATV operators began importing programming from a number of independent TV stations, the original "Superstations" were born. The superstations are independent TV stations that utilize long-haul microwave networks and/or satellites to provide programming to viewers hundreds of miles away.

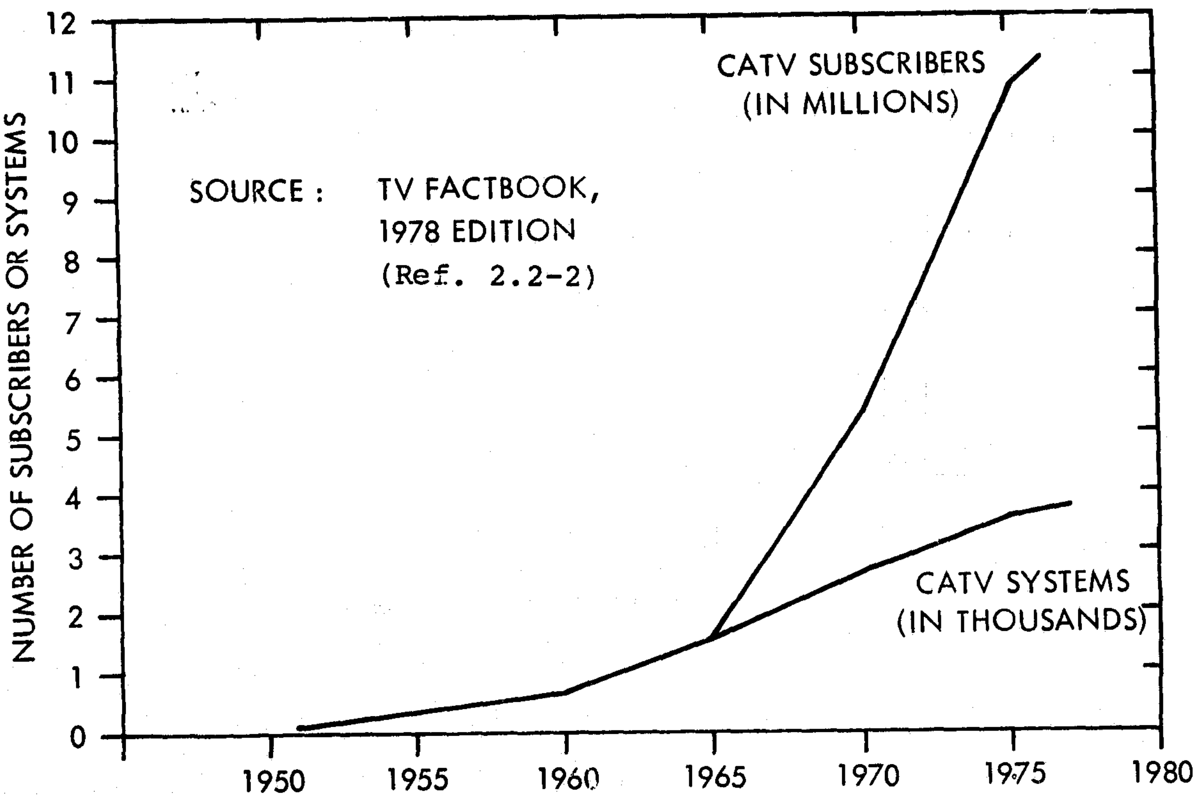

FIG. 2.2-1. GROWTH OF THE CATV INDUSTRY

More recently a new form of CATV service has emerged: pay TV. For a premium, subscribers may view first run movies, shows, and special events that are not otherwise available through the TV networks. This added program diversity has given new impetus to the industry and provides CATV with a competitive advantage over "free" TV in metropolitan areas. As a result, the CATV subscriber base has increased significantly in the last few years (Fig. 2.2-2). From 1976 to 1978 the number of CATV subscribers also subscribing to pay TV has quadrupled from 300,000 to 1,200,000 or from 4.5 percent to nine percent of all CATV households.

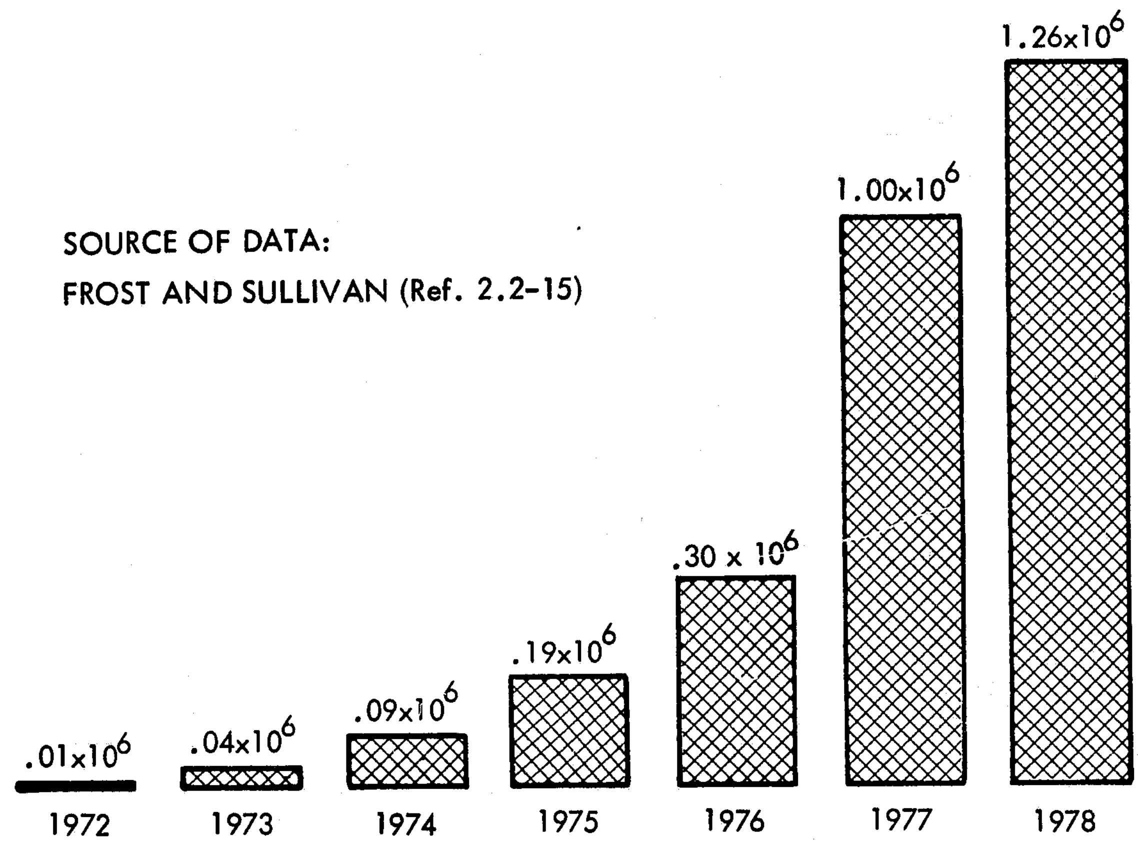

FIG. 2.2-2. NUMBER OF PAY TV SUBSCRIBERS

The networks and established TV stations view the growth of CATV with alarm and show concern over a possible loss of viewers. These fears are reinforced by the growing number of households with access to cable TV (Table 2.2-5). The stations fear that advertisers will switch to CATV once CATV household penetration reaches 30 percent (B. Donnelly, Young & Rubicam, N.Y. Times 12/3/78), a point which many observers forecast by the mid 1980s (Table 2.2-6). The TV networks have resisted CATV via restrictions imposed by the FCC which have had a dampening effect on CATV growth. However, more recent FCC rulings have given a considerable degree of freedom to CATV operators (Wall Street Journal 12/20/78 and 3/30/79; Business Week 1/27/78) and have placed CATV on the threshold of becoming a significant alternative source of entertainment for the American public.

TABLE 2.2-5. HOUSEHOLDS WITH ACCESS (1) TO CABLE TV

Year	Percent of Households	Source
1978	35	International Resource Development Inc.
1990	85	"
2000	100	"

(1) Area is served by feeder cable

TABLE 2.2-6. ESTIMATED HOUSEHOLD PENETRATION BY CABLE TV

Year	Household Penetration	Source
1976	15%	Frost & Sullivan 6/78
1978	18%	Broadcasting Mag. 5/1/78
1980	20%	Frost & Sullivan
1981	30%	B. Donnelly - Young & Rubicam
1985	30%	J. Goodman - NBC
1986	29%	Frost & Sullivan

Satellite carriers have been quick to respond to the needs of the CATV industry. The primary supplier has been RCA using the facilities of SATCOM I. RCA has announced its intention to launch SATCOM III one year ahead of schedule to meet the growing demand by CATV programmers (Wall Street Journal 12/5/78) and intends to shift the 18 CATV programmers now using SATCOM I to SATCOM III. All of SATCOM III's 24 transponders, and some of those on SATCOM I, will be dedicated to CATV customers. Western Union, which now carries distribution feeds from the Hughes Television Network, Robert Wold Inc., the Spanish International Network, and PBS's programming, is planning to launch Westar III, also in advance of schedule, and will actively pursue the CATV market currently dominated by RCA. At the same time, the number of CATV earth stations has expanded from virtually zero in 1975 to 1300 by the end of 1978, and is expected to more than double to 3750 by the end of 1981 (Fig. 2.2-3).

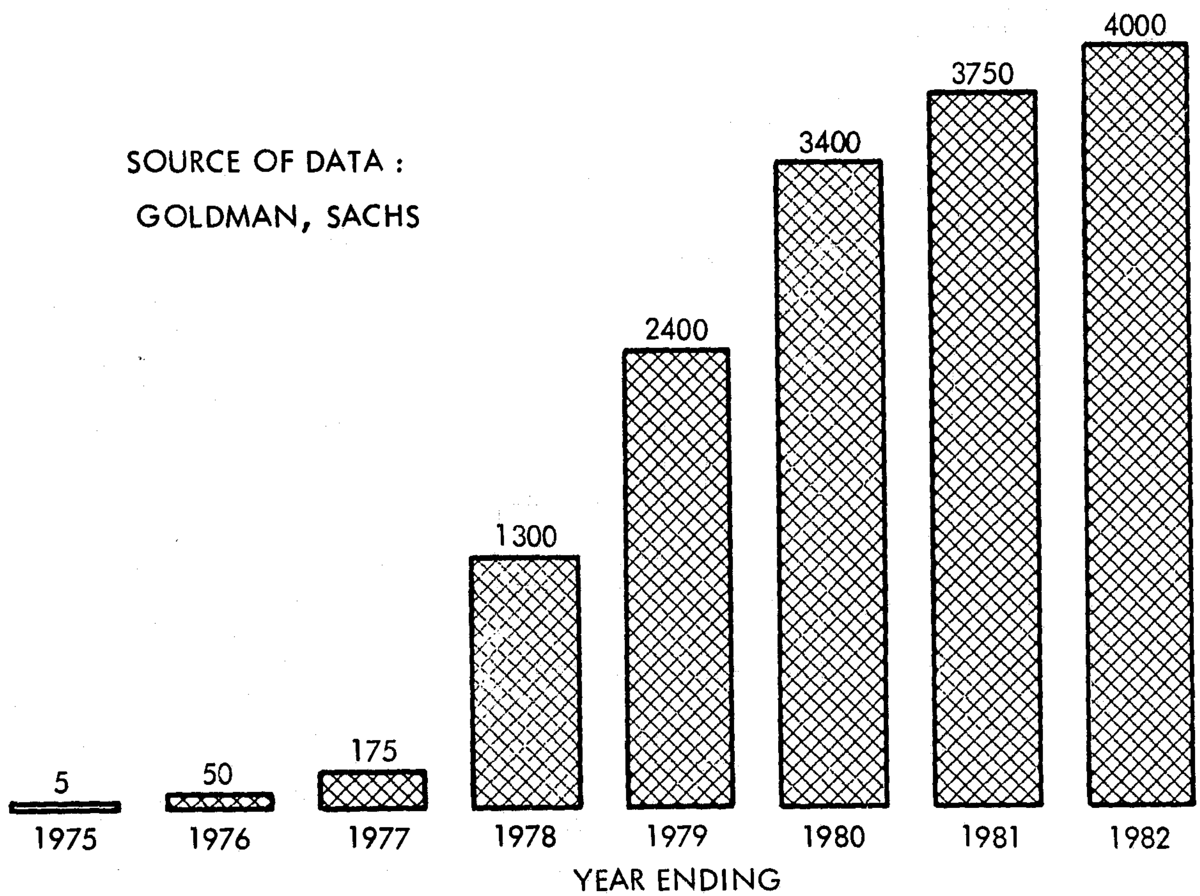

FIG. 2.2-3. NUMBER OF INSTALLED EARTH STATIONS

CATV faces a seemingly bright future propelled by a large demand for alternative entertainment. This demand is far from being saturated (over 80 percent of households are not currently connected by cable and over 98 percent do not subscribe to pay TV), and the possibility exists for massive infusions of revenue from advertisers once household penetration exceeds 30 percent. There are, however, two dark clouds on the industry's future which may hamper its growth and consequently react on the potential demand for satellite channels. The introduction of home video disk players by Magnavox (Wall Street Journal 12/3/78) and RCA (N.Y. Times 1/10/79) and others offers a low cost alternative to CATV. With disks currently costing between $10 and $17 consumers will be able to buy, keep, and play at will many of the programs that have been the driving force behind CATV's growth. Additionally, the high cost of developing new programs on the one hand, and the rapid rate at which existing program material is used on the other, may tend to dry up the source of new programming to the CATV industry.

Superstations will face an increasingly difficult time in procuring syndicated programs (Wall Street Journal 1/9/79) and only those with a tie to local sports teams combined with a large movie stock will be able to offer attractive programming on a wider than local basis (N.Y. Daily News 1/18/79). As such, superstation channel demand will remain constant overall, but will shift from largely terrestrial to satellite transmissions.

The preceding discussion is reflected in the video channel demand forecast for CATV presented in Table 2.2-7. The forecast postulates a continuing, though moderating, growth for wideband channels by program originators and distributors. Part of the growth will be due to new programs (Wall Street Journal 12/5/78) or new suppliers, and part to the utilization of two channels for East and West Coast broadcasts (HBO, Showtime, Warner, etc.).

As shown in Table 2.2-7, total demand for CATV channels grows from 35 to 60 video channels, averaging a modest 2.7 percent growth rate over the 1980 to 2000 time span.

TABLE 2.2-7. CATV CHANNEL DEMAND FORECAST (VIDEO CHANNELS)[1]

	1978	1980	1990	2000
Program originators and distributors [2]	17	22	37	47
Superstations [3]	13	13	13	13
Total	30	35	50	60

(1) Subject to bandwidth compression as per Section 2.4

(2) 1978 - Current SATCOM I and Westar channels
1980 - Projected SATCOM I, SATCOM III, and Westar Channels
1980-1990 - Moderate growth including other carriers
1990-2000 - Onset of saturation

(3) Source of Data: Association of Independent TV Stations

2.2.4 VIDEOCONFERENCING

Videoconferencing represents an important step in the direction of an electronic society incorporating the concept of moving ideas electronically rather than physically. It offers a cost-efficient alternative to some travel, and allows a greater utilization of personnel time resources. At a time of energy shortages, a method that reduces U.S. fossil fuel energy requirements ranks as a national priority.

On the other hand, two important issues exist concerning the real need and potential for videoconferencing. The first involves the degree to which personal interaction can successfully be replaced by remote communications. The second issue relates to whether the additional cost of full-video can be justified when compared to relatively low cost narrowband teleconferencing using voiceband channels alone.

The inauspicious record of AT&T's Picturephone during the 1960s has generated some negative attitudes toward videocommunications. The Picturephone failure was due to a number of factors, including poor resolution, a small screen, and a high price tag. Users questioned the added value of the higher cost video over audio. More recently, AT&T has repackaged its video service and is currently experimenting with a concept called Picturephone Meeting Service (PMS) which utilizes central videoconferencing facilities as opposed to establishing facilities in the offices of individual executives.

A large number of other experiments have been conducted to measure acceptance and utilization levels for videoconferencing. Most notably, studies in the UK by the Communications Studies Group (Ref. 2.2-3) and in Canada by Bell Canada (Ref. 2.2-4) and University of Quebec (Ref. 2.2-5) have attempted to measure attitudinal as well as real requirements in teleconferencing.

Travel and communication interactions involve more than a simple question of economic trade-off. Some managers regard travel as an attractive side benefit while others have a more negative attitude towards travel. Attitudinal studies toward business travel have indicated that an inverse relationship exists between the desire for more travel and the current level of travel. A Bell Canada study of 9,619 people who traveled on business showed that, while 31 percent of those who travel 0-5 times a year have a desire to increase the number of trips, only seven percent of those who traveled 30 or more times a year wanted to increase the number of trips. Overall, 15 percent of the respondents indicated they would want to increase the number of trips, while 37 percent wanted travel to decrease, and 48 percent wanted it to stay the same. A private study by Roger Pye

(Ref. 2.2-6) of 145 managers and professionals in England had similar results: seven percent wanted more travel, 28 percent less, and 35 percent about the same.

A factor in determining the acceptability of teleconferencing relates to the attitudes of users towards different teleconferencing media. A study of 54 American executives has shown that audio conferences were considered to be less friendly than video or face-to-face conferences, but that video and face-to face conferences were thought to be equally friendly (Ref.2.2-7). Similarly, users of Bell Canada's video conference system and the University of Quebec's audio system have indicated that videoconferencing is more friendly and more like a face-to-face meeting than audio conferencing. Most investigators agree that some types of meeting are suitable for replacement by teleconferencing, that travel has some negative attributes (other than cost), and that many would be amenable to replacing travel by teleconferencing.

A number of studies have offered estimates of the degree to which teleconferencing can replace business travel. Table 2.2-8 lists these. In each case a sizable potential for teleconferencing has been postulated and a significant portion of this teleconferencing requires the added capabilities of video. However, any forecast of videoconferencing demand must deal with the questions of why there has so far been only limited activity in this area.

TABLE 2.2-8. SUITABILITY OF VARIOUS CONFERENCE MODES

	Face-to-Face Meetings	Teleconferencing	
		Video with Audio Support	Audio with Graphics Support
SBS - Project Prelude Systems Strategy Dept. BPO	59%	Some 2%	39%
Stanford Research Institute	47%	8%	45%
Xerox	50%	9%	41%
Bell Labs	50%	10%	40%
NYU Alternate Media Center	50%	10%	40%
James Martin	40%	20%	40%
UK Communications Study Group	34%	23%	43%
Future Systems Inc.	62.5%	37.5%	-
Dayton Research Institute	50%	50%	-

The cost factor is probably the chief explanation for the lack of success of videoconferencing to date. However, emerging trends appear to be highly likely to change this situation. Oil prices have increased in quantum leaps since 1973. With the expected depletion in oil reserves adding to an unstable political situation, prices will continue to rise sharply and shortages which have already emerged will intensify. Travel, as a result, will become a much more expensive and difficult method for conducting business. At the same time, it is likely that technology in the form of satellite transmission and fiber optics will greatly reduce the cost of video communications while making the teleconferencing process more efficient and convenient for the user.

A number of organizations are now using videoconferencing (Table 2.2-9) and, contrary to the poor showing of AT&T's original Picturephone, the new Picturephone Meeting Service is apparently much more successful. The New York PMS center is reportedly booked about 85 percent of the time. Furthermore, the fact that 70 percent of the users are repeat customers indicates overall satisfaction with the system even though advanced reservations and travel to a central location are required.

The cost of videoconferencing, currently tariffed by AT&T's Picturephone Meeting Service, compares favorably with the cost of much of business travel. For example, typical round trip air fare for two people from New York to Chicago is $460. Allowing $50 for local transportation, $50 for meals, and $80 for overnight hotel expenses results in a total trip expense of $640. In comparison, the PMS charge of $4.50 per minute between New York and Chicago would permit well over two hours of teleconferencing for the same expenditure. Furthermore, if reasonable allocations are made for the cost of travel time, the balance clearly favors videoconferencing. Generally, for short meetings, involving many participants, videoconferencing is the lower cost alternative. Similarly, PMS is more cost-effective than travel when the distances involved are great, particularly when overnight stays are required. Thus PMS is able, in many cases, to compete favorably in cost today. The comparison based on today's costs is expected to become overwhelmingly favorable to videoconferencing, as the trends of increasing travel costs and decreasing communications costs continue.

While costs for public videoconferencing services like PMS will become increasingly competitive with travel as time goes on, designers of private videoconferencing systems must consider the investment necessary to create the videoconferencing centers. Typical costs for these centers are in the range of $100,000 to $200,000 (Ref. 2.2-8). Assuming that centers are established only

TABLE 2.2-9. ORGANIZATIONS USING VIDEOCONFERENCING

Organization	Approx. Usage	Avg. Mtg. Duration (Hours)	No. of Participants	Meeting Type*	Status
Bell Canada	1/day	2.3	3-6	1-3	Operational
Bell Labs	2-4/wk.	2.1	3-6	1-3, 7	Operational
Confravision-U.K.	Modest	1-2	6-8	1-3	Operational
Confravision-Eur.	Very little	---	---	1-3	Operational
AT&T PMS	Modest	1-2	4-6	1-3	Operational
Citibank	50/wk.	1-3	3-6	1	Out of Serv.
Bankers Trust	3-5/wk.	1-3	3-6	1	Out of Serv.
Australian P.O.	Modest	1-2	6	1-7	Operational
Dow Chemical	1-3/wk.	1	3-6	1,2,7	Operational
N. Y. Telephone	Very modest	1-2	---	1-3	Operational
Nippon Tel & Tel.	---	2	4-6	---	Operational
Metropolitan National Council	10 hrs/wk.	1	10-100	5	Operational

*1 - Routine Business Meetings
2 - Informal Information Exchange
3 - Urgent Meetings
4 - Meetings prior to Face-to-Face Meetings
5 - Teaching, Training or Instruction
6 - Sale Presentations
7 - Research

Source: Stanford Research Institute, May 1977

at locations with 1000 or more employees, the total U.S. investment in centers for videoconferencing would be in the $0.9 to $1.8 billion range. Amortized over a 10-year period, the annual capitalized expenditure would be $90 to $180 million and operating expenditures would be about $450 million. Thus, total U.S. annualized cost of an advanced videoconferencing system would be in the order of $0.6 billion. By way of comparison, over $8 billion was spent by U.S. business during 1977 on air travel (fares alone).

Based on these considerations and on estimates for the amount of travel for which videoconferencing can be substituted (Ref. 2.2-9), the forecasted demand for videoconferencing through the year 2000 is shown in Table 2.2-10.

TABLE 2.2-10. VIDEOCONFERENCING DEMAND

	1980 (1)	1990	2000
1) Enplanements (2)		383×10^6	575×10^6
2) Business enplanements at 40% (3)		153.2×10^6	230×10^6
3) Round trips (3)		76.6×10^6	115×10^6
4) x 2.7 conferences per trip ÷ 2 people traveling per conference (3)		103.4×10^6	155.3×10^6
5) Potential for video replacement at 8% (3)		8.3×10^6	12.4×10^6
6) Realized percentage		10%	25%
7) No. of Videoconferences per year	5000	830,000	3,100,000

(1) Based on estimate of current number of videoconferencing centers
(2) Federal Aviation Administration
(3) SRI, Technical assessment of Telcom/Transportation Interaction

Videoconferencing demand is estimated for 1980 on the basis of 15 public Picturephone Meeting Service centers (in 12 cities), twelve centers for internal AT&T usage, and a number of centers for NASA and other users. As shown in Table 2.2-10, these centers are expected to generate 5000 videoconferences annually in 1980. For 1990 and 2000 the potential displacement of air travel was used as the methodology for forecasting videoconferencing demand. The number of enplanements appearing on line 1 of Table 2.2-10 was multiplied by 40 percent to derive business travel (line 2) and further reduced by a factor of two to arrive at the number of round trips (line 3). Line 4 calculates the number of business conferences under the assumptions that two people travel to attend each conference and on the average 2.7 conferences result from each trip. As shown on line 5, eight percent of the conferences are considered suitable for replacement by videoconferencing. Using the assumption that of those conferences suitable for video, 10 percent and 25 percent are actually realized in the years 1990 and 2000, results in the number of videoconferences per year shown on line 7. As may be seen from the values presented in Table 2.2-10, the number of videoconferences increases from a low value of 5000 in 1980 to 830,000 in 1990 and 3,100,000 in 2000. Videoconferencing therefore can be expected to contribute a significant component of the demand for video channels in the years 1990 and 2000.

2.2.5 EDUCATIONAL VIDEO

The educational community is entering a period of rapid change. Between 1980 and 1995, the number of college-age students in the USA is expected to decline by 25 percent (Ref.2.2-10). Colleges and universities are faced with declining enrollment and escalating costs and as a result will be faced with the need to: (1) Reduce expenditures to reflect decreasing tuition revenues, and (2) Seek students from other segments of society.

At the same time increasing interest in continuing education is evident among the adult population. Table 2.2-11 presents the results of a recent study (Ref. 2.2-11) indicating the high degree of interest already existing in this population. A large market for continuing education can develop if convenient and economic means of delivery are provided.

TABLE 2.2-11. INTEREST IN CONTINUING EDUCATION

- 23 percent of adults are interested in non-degree continuing education
- 27 percent of adults are interested in education leading to a degree
- 64 percent think they could successfully complete more education
- 46 percent wish they had acquired more education
- 38 percent want more education for job or career advancement
- 32 percent want more education for self development
- 66 percent want to continue learning
- 80 percent think media and technology could be used to improve access to education

Source: "Telecommunications for Metropolitan Areas: Opportunity for the 1980s" National Research Council, U.S. Department of Commerce (Ref. 2.2-11).

A number of states currently operate microwave networks interconnecting dispersed campuses. In addition, the Appalachian Project and others (Table 2.2-12) have used the ATS and CTS satellites, on an experimental basis, to deliver educational programs to geographically dispersed locations. Results have been favorable to the acceptability of the remote classroom concept.

TABLE 2.2-12. EXPERIMENTS RELATED TO EDUCATIONAL VIDEO ON ATS-1, 3, 6 AND CTS SATELLITES

Experiment	Time Period	ATS-1	ATS-3	ATS-6	CTS
Washington, Alaska, Montana, Idaho Program	1974-1978	X		X	
Alaskan Education Experiment	1974-1975	X		X	
Appalachian Education Satellite Program	1974-1975		X	X	
Satellite Technology Demonstration	1974-1975		X	X	
National Education Assoc. Experiment	1975-1976	X	X		
Univer. of South Pacific Experiment	1974-1978		X		
Department of Interior Satellite Project	1977-1978	X			
Appalachian Regional Commission	1977-1978		X	X	
Agency for International Develop. University of West Indies Experiment	1978		X	X	
Archdiocese of San Francisco Interchange Experiment	1976-1978				X
Southern Educational Communities Assoc.	1976-1978				X

It appears that educational video systems offer a promising vehicle for interfacing the needs of colleges and universities for new students with the desires of large segments of the population for continuing education.

The cost of providing video channels for educational uses compares favorably with current costs for instruction. Instructional salaries average $20,000 per year with workloads of 200 hours per year being typical. This amounts to a cost for instruction alone of about $100 per hour.

Present tariffs for video channels provide a data point for comparison with the above. The monthly cost under AT&T's tariff for Series 7000 full-time TV channels is $55 per mile plus a charge of $1500 for each multidrop connection. Thus, a 500-mile multidrop configuration (typically connecting six remote campuses within a state) would cost approximately $37,000 per month. On the basis of 200 hours of usage per month, the per classroom-hour cost is $35 for each of the six locations. This result compares favorably with the previously mentioned $100 per hour cost for present day instruction.

The above is intended to provide only rough, order of magnitude comparisons. Many other factors must be taken into account to fully evaluate cost tradeoffs such as overhead on instructors salaries, fees for the centrally located instruction, the possible requirement for classroom monitors, and the need for outside of classroom instructional activities such as paper grading.

In addition, the following trends will make the use of video channels for educational purposes even more cost competitive in the future:

(a) Video compression techniques are expected to permit a six-to-one bandwidth compression by 1990 while maintaining quality adequate for classroom purposes.

(b) Compensation for lecturers has doubled over the last decade (Ref. 2.2-12) and this trend appears to be continuing in contrast with video costs which are decreasing.

(c) Unused capacity available during night and weekend hours can be used for other applications (data transmission, community affairs, etc.).

Based on these considerations, Table 2.2-13 forecasts channel demand for educational video service. The forecast considers three applications: Intrastate - which contributes the

greatest portion of the demand; Interstate - serving certain educational organizations with broader reach; and Specialized - programs for specific applications such as agriculture, consumer education, vocational, etc.

As shown in Table 2.2-13, only intrastate usage is significant in 1978 and 1980. Interstate and specialized applications exist only as part of experimental programs. By 1990, the forecast includes: statewide video systems in approximately 30 states (each transmitting four channels) plus five interstate systems (four channels each) and some specialized systems (25 channels). By the year 2000, intrastate networks will require 400 channels and requirements for interstate and specialized applications are expected to double, reaching 50 channels each.

TABLE 2.2-13. EDUCATIONAL VIDEO-CHANNEL DEMAND (VIDEO CHANNELS)[1]

	1978	1980	1990	2000
Intrastate	12	15	120	400
Interstate[2]	--	--	20	50
Specialized[2]	--	--	25	50
Total	12	15	165	500

(1) Subject to bandwidth compression as per Section 2.4

(2) Experimental uses only for 1978 and 1980

The total communications demand for educational video grows from 15 channels in 1980 to 165 in the year 1990 (average growth rate 27 percent per annum). Between 1990 and the year 2000, the average growth rate moderates to 12 percent per year, resulting in a forecast demand for 500 channels (subject to bandwidth compression as discussed in Section 2.4). While the total shown for the year 2000 amounts to a sizable demand for communications, the classroom hours projected for video transmission amount to less than one percent of current total classroom hours, allowing for considerable penetration before any saturation effects need be accounted for.

2.2.6 HEALTH AND PUBLIC AFFAIRS

There has been considerable interest in the utilization of video communications in areas relating to Health and Public Affairs (Ref. 2.2-13), and a number of experiments conducted on ATS and CTS satellites have explored some of these possibilities with respect to the special role of satellite communications (Table 2.2-14). The demand forecasts contained in this section consider the general areas of:

(1) Health Services - Table 2.2-15 illustrates some typical applications of video telecommunications in the area of Health Services. This segment includes a number of different aspects, some of which (medical conferences, medical education) were included under Videoconferencing and Educational Video. Other medical applications of video such as telediagnosis are included in the present section. Telediagnosis addresses the fact that while medical specialists tend to concentrate in urban centers, large segments of the population live in rural or remote areas. Telediagnosis utilizes a video channel linking the doctor and a distant patient. A paramedical attendant assists in the examination procedure at the remote site. The more general category of Telemedicine carries the process one step further and allows the doctor to remotely view and supervise treatment.

(2) Public Affairs - Opening government to the people and allowing constituents to interact with their elected officials has long been a goal of a democratic society. Recently, congressional meetings have been televised live to the general public and a number of experiments on open government, most notably involving interactive TV (N.Y. Times 11/20/70), have been conducted. The desire on the part of elected officials for information on public attitudes, and an increasing demand for influencing policy by the electorate, have created a need that is addressable by video technology. Since the need is characterized in most cases by a one (elected official) to many (constituents) scenario, one-way video communication combined with an interactive, non-video, response method is appropriate.

Other applications for video falling under the category of Public Affairs are law enforcement (police line-ups), courts (witness depositions), and disaster relief support (video examination of a disaster struck area).

TABLE 2.2-14. EXPERIMENTS RELATED TO HEALTH AND PUBLIC AFFAIRS ON ATS - 1, 3, 6, AND CTS SATELLITES

Experiment	Time Period	ATS-1	ATS-3	ATS-6	CTS
Indian Health Service Experiment (IHS)	1974-1975	X		X	
Veterans Administration Experiment (VA)	1974-1975			X	
Project Lookup (PLU)	1977-1978			X	
Mountain States Health Corporation Experiment (MSHC)	1978			X	
Lister Hill Center Bio-medical Communications Experiment	1976-1978				X
Veterans Administration Health/Communications Experiment	1977-1978				X
Public Service Satellite Consortium (PSSC) Experiment	1977-1978				X
George Washington University Videoconferencing for Congress Experiment	1977-1978				X

TABLE 2.2-15. SUMMARY OF TWO-WAY VISUAL TELECOMMUNICATION PROJECTS INITIATED IN JUNE 1972 TO EXPLORE THE UTILITY OF THIS TECHNOLOGY IN HEALTH-SERVICES DELIVERY

Institution	Title	Technology
Illinois Mental Health Institutes	Picturephone Network for the Illinois Department of Mental Health Medical Center Complex/Community Mental Health Program	Picturephone
Case Western Reserve University	An Experiment in Using Two-Way Wide-Band Audio, Visual and Data Communications Over a Laser Link to Permit an Anesthesiologist to Supervise a Nurse Anesthetist	Laser One-way color, one-way black and white Remote Controls
Cambridge Hospital	Evaluation of a Video-Augmented Consultation System Between Physician Extenders at Neighborhood Health Clinics and Physicians at a Community Hospital	Microwave Black and White
Bethany Brethren	Picturephone and Cable for Visual Communication and Transmission of Medical Records in the Bethany/Garfield Community Health Care Network	Picturephone Cable, video discs Black and White
Lakeview Clinic	Bidirectional Cable Television System to Support a Rural Group Practice	Cable Portable video carts Black and White
Dartmouth Medical School	Two-Way Television to Support Physician Extenders in Dermatology and Speech Therapy	Microwave One-way color, one-way black and white
Mt. Sinai School of Medicine	Bidirectional Video Communication and Facsimile Reproduction Links Between a Housing Project Pediatric Clinic and the Mount Sinai Medical Center	Cable Black and White

Source: "An Overview of Some Technological/Health-Care System Implications of Seven Exploratory Broad-Band Communications Experiments," Maxine L. Rockoff, IEEE Transactions on Communications, Oct. 1975.

Table 2.2-16 indicates the forecasted channel demand for the Health and Public Affairs category. As noted, in 1980 some demand will be met on an experimental basis only. By 1990, some of the demand, dominated largely by telemedicine requirements, is expected to be translated into practical applications as technology provides economic and flexible video transmission. The forecast is based in part on studies conducted by a Public Satellite User Requirement Workshop (Ref. 2.2-14), which provides some demand estimates without specifying a definite timing. In view of the increasing cost of physical travel, the sky-rocketing costs of health care, and the desire for larger involvement by the public in the governmental process, an overall seven percent per annum growth between 1990 and 2000 appears to provide a conservative estimate.

TABLE 2.2-16. CHANNEL DEMAND FOR HEALTH AND PUBLIC AFFAIRS (VIDEO CHANNELS)(1)

	1980(2)	1990	2000
Telemedicine	---	15	30
Public Affairs	---	10	20
Total	---	25	50

(1) Subject to bandwidth compression as per Section 2.4
(2) Experimental uses only for 1980

2.2.7 SUMMARY OF VIDEO SERVICES DEMAND

Table 2.2-17 summarizes the demand for Video Services for the years 1980, 1990, and 2000. The estimates include only those components of traffic that travel far enough to be attractive targets for satellite transmission (nominally 200 miles or more).

The results presented in Table 2.2-17 are in units appropriate to the individual applications as developed in the preceding pages. Thus, for example, Network TV and CATV are expressed in terms of wideband video channels while videoconferencing is presented in terms of the number of conferences per year. Several steps are necessary to convert these application-specific units to a common measure permitting the aggregation of the results and the evaluation of demand for satellite capacity. The problem of this conversion is addressed in Section 2.4.

TABLE 2.2-17. SUMMARY OF VIDEO SERVICE DEMAND

	UNITS (1)	1980	1990	2000
Network TV (2)	Video Channels	10	12	16
CATV	Video Channels	35	50	60
Videoconferencing	Teleconferences per Yr.	5×10^3	830×10^3	3100×10^3
Educational Video	Video Channels	15	165	500
Health and Public Affairs	Video Channels	0	25	50

(1) Video Channels subject to bandwidth compression. See Section 2.4 for conversion to common units.

(2) Does not include occasional use of an additional 15, 18, and 19 channels in 1980, 1990, and 2000.

2.3 DATA SERVICES DEMAND

Data Services refers to a wide variety of telecommunications activities ranging from low speed TWX/Telex services to high speed facsimile transmission and includes such diverse items as computer-to-computer transmissions and electronic mail. This is an area in which advancing technology may be expected to have an important impact on traffic demand.

2.3.1 CATEGORIES OF DATA TRAFFIC

The following categories were selected as convenient groupings for the analysis of traffic demand.

(a) Message Traffic - Primarily composed of record communications between individuals and/or organizations.

(b) Computer Traffic - Includes Inquiry/Response traffic between terminal and computer, plus computer network traffic for distributed processing, funds transfer, and data base exchange.

(c) Narrowband Teleconferencing - Image and character oriented data traffic in support of Audio/Graphic teleconferencing plus freeze-frame television.

These categories, and the subcategories which make them up, are listed in Table 2.3-1, which also provides a brief indication of the investigative procedure used in projecting traffic demand for each subcategory.

2.3.1.1 Message Traffic Category

As indicated in Table 2.3-1, message traffic is treated under four subcategories. The first two relate to traditional types of message traffic, namely, TWX/Telex and conventional facsimile. Both of these services have a substantial history on which traffic volumes and future growth projections can be based. In particular, traffic projections into the future may be related to existing terminal populations and extrapolated growth rates for these populations.

The remaining components of the message traffic category listed in Table 2.2-1 ("Electronic Mail-Image" and "Electronic Mail-Character") have, so far, only lightly penetrated their potential markets. Important segments of present day paper document delivery services are confidently predicted to evolve toward fully electronic transmission modes. These are in addition to, and supplement or replace, the more fully developed modes covered by TWX/Telex and facsimile. Since historical data relating to these newer traffic components has not yet

developed sufficiently to establish trends, the projection of data traffic to future years must rely on more fundamental predictive approaches. The approach adopted in this study evaluates these categories of data traffic in terms of the potential displacement of a percentage of paper document delivery demands.

TABLE 2.3-1. DATA TRAFFIC CATEGORIES

CATEGORY	SUB-CATEGORY	DEMAND ANALYSIS PROCEDURE
MESSAGE	TWX/TELEX	EXTRAPOLATED TERMINAL POPULATION
	TRADITIONAL FAX	EXTRAPOLATED TERMINAL POPULATION
	ELECTRONIC MAIL-IMAGE	DISPLACEMENT OF PAPER DOCUMENT DELIVERY
	ELECTRONIC MAIL-CHARACTER	DISPLACEMENT OF PAPER DOCUMENT DELIVERY
COMPUTER	TERMINAL/CPU	EXTRAPOLATED TERMINAL POPULATION
	CPU/CPU	PERCENT OF TERM/CPU TRAFFIC PLUS EFT
NARROWBAND TELECONFERENCING	FAX	DISPLACEMENT OF AIR TRAVEL
	CHARACTER	DISPLACEMENT OF AIR TRAVEL
	FREEZE FRAME	DISPLACEMENT OF AIR TRAVEL

2.3.1.2 Computer Traffic Category

The second of the major categories of data traffic demand, Computer Traffic, represents the rapidly growing requirements for computer communication. Two important sub-categories of computer traffic are considered. The first of these, Terminal/CPU traffic, has already experienced considerable development and growth, and therefore may be studied by extrapolating historical trends, chiefly terminal population statistics.

The second component of computer based data traffic, CPU/CPU, is less well developed and therefore more elusive. A major contributor to this traffic is expected from those

data base adjustments and other exchanges between CPUs resulting from the increasing trend toward distributed processing. Since the data bases themselves primarily originate through terminal to CPU activity, this component of CPU/CPU traffic may be estimated as some fraction of the projected Terminal/CPU traffic. Additional contributions to CPU/CPU traffic are expected as the result of data base exchanges between remote computers which are not reflected in the Terminal/CPU traffic base. The largest component of traffic of this type is the result of Electronic Funds Transfer activities and a separate contribution to CPU/CPU traffic resulting from these activities has been included. There are many other contributors to CPU/CPU traffic such as point of sale systems, automatic sensor and metering systems, etc. Their traffic demands, however, are either of relatively low volume, or are confined to a local city area and are therefore not expected to impact the longer distance transmissions appropriate to this study.

2.3.1.3 Narrowband Teleconferencing Category

The third major category of data traffic listed in Table 2.3-1 consists of traffic in support of narrowband teleconferencing. As the convenience and costs of telecommunications improve relative to those of travel, an increasing fraction of business travel will be displaced by teleconferencing. Three components of the resulting data traffic demand have been considered: page image oriented (facsimile), character oriented, and freeze-frame TV. In each case the demand has been estimated as a fraction of potential travel, but the data rates and channel usage patterns differ considerably for each component. The predictive approach taken for this traffic is similar to that followed in the section dealing with full-video support of teleconferencing. In the narrowband case, however, only those teleconferencing aids that can reasonably be supported within the bandwidth and data rate constraints of a voice channel (as opposed to the much wider band video channel) have been included.

2.3.2 MESSAGE TRAFFIC DEMAND

The following paragraphs develop estimates for traffic demand for each of the Data Services subcategories.

2.3.2.1 TWX/Telex traffic Demand

TWX and Telex are the nation's two major teletypewriter networks. Other services such as telegram, mailgram and money order have similar general characteristics from the viewpoint of traffic demand, but do not significantly affect volume predictions. Subscriber-to-subscriber exchange service for both TWX and Telex is supplied by Western Union which acquired TWX from the Bell System in 1971.

Telex, which was introduced in the U.S. by Western Union in 1958, provides a 66-word per minute, message oriented service using five-level ITA No. 2 Code. As part of the expansion program, Telex is being equipped with advanced time-division digital switches to more effectively interface it with the existing 9000 mile Western Union terrestrial microwave network, and with the Westar satellite system. The expansion program will also enhance interoperability with TWX and provide user conveniences and added network efficiency.

TWX is in most respects very similar to Telex, but uses ASCII code at 100 words per minute. The TWX expansion program will result in the transfer of the TWX network from the national switching and transmission facilities of the Bell System to Western Union facilities. The digital network established for Telex will form the backbone for this transfer, but since TWX subscribers use modems and analog transmission, a complex interface capability is being engineered. When completed, TWX concentrators will have been installed in 1600 U.S. cities.

A number of estimates for various TWX/Telex related parameters have been published. Since these take several different forms, a conversion to the common denominator of messages per year has been selected as a means of permitting comparison. Those estimates that are presented in terms of terminal populations have therefore been converted to messages per year by assuming five messages per day per terminal and 250 days per year. Estimates presented in terms of common carrier revenues have similarly been converted to messages per year by dividing by $1.60 per message.

Table 2.3-2 lists several of the available estimates, identifies the source, the conversion factor used, and the resultant messages per year.

TABLE 2.3-2. TWX/TELEX ESTIMATES

PERIOD	ESTIMATE	CONVERSION FACTOR	MSGS/ YEAR	SOURCE
1975	100,000 Terminals 4-6%/yr. growth	1250 msg/yr per terminal	125M	Business Communications, 1975-1985 May 1975, A.D. Little
1974	$200M Comm. Carrier Revenue	$1.60/ message	125M	"
1980	$250-280 Comm. Carrier Revenue	$1.60/ message	156-175M	"
1977	111,000 Terminals	1250 msg/yr per terminal	139M	Cost-Effective Switching System Design - L.Stier,Western Union Info. Systems, Telecomm. Aug. 1977
1976	108M Pgs/Yr	1	108M	Xerox Corp. Petition for Rule Making before FCC Nov. 16, 1978, App.C
1978	$245M Comm. Carrier Rev.	$1.60/Msg.	153M	Telecomm. Market Opportunities in the US, 1978; Internat'l. Resource Devel. Inc., April 1978
1980	$270M	$1.60/Msg.	168M	"
1983	$295M	$1.60/Msg.	184M	"
1988	$325M Comm. Carrier Rev.	$1.60/Msg.	203M	"
1970	80,000 Terminals	1250 Msg/Yr per terminal	100M	Impacts of Electronic Comm. Systems on the U.S.P.S. 1975-1985, C-80209 Feb. 14, 1977, A.D. Little, P4-9
1975	106,000 Terminals	1250 Msg/Yr per terminal	133M	"
1985	145,000 Terminals	1250 Msg/Yr per terminal	181M	"
1980	156M Msgs/Yr	1	156M	"
1971	81,000 Terminals	1250 Msg/Yr	101M	Communications News Dec. 1978, P29
1972	89,000 Terminals	"	111M	"
1973	97,000 Terminals	"	121M	"
1974	102,000 Terminals	"	128M	"
1975	105,000 Terminals	"	131M	"
1976	110,000 Terminals	"	138M	"
1977	115,000 Terminals	"	144M	"
1978	119,000 Terminals	"	149M	"

The values presented in Table 2.3-2 are displayed graphically in Figure 2.3-1. The growth rate from 1970 to 1980 averages slightly more than five percent per year, and reflects public acceptance of a viable form of character oriented electronic mail. The continued acceptance of this relatively slow and costly form of message communication, however, becomes less likely as competition from higher speed services tied to newer terminal types expands. This is recognized by Western Union in its plans for modernization. A.D. Little (Ref. 2.3-1) predicts a peaking in the 1980 to 1985 period, which appears likely in terms of the rapid growth of other competing services. The solid curve in Fig. 2.3-1 shows the predicted demand to the year 2000 based on the peak occurring around 1983, and with demand falling at three percent per annum from 1985 to 1990. This is followed by a steeper five percent decline in the decade from 1990 to 2000, as existing equipment is retired in favor of more advanced systems.

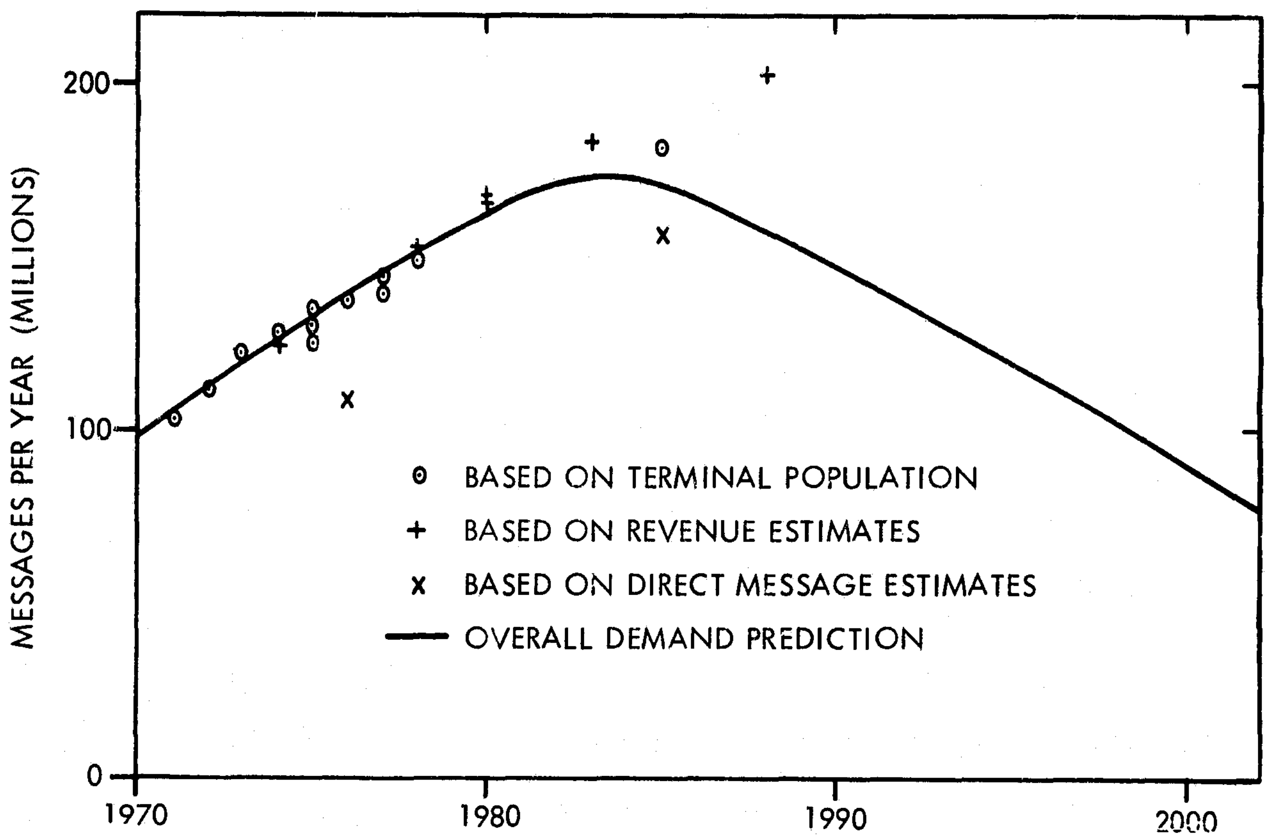

FIGURE 2.3-1. TWX/TELEX MESSAGES PER YEAR

It is important to note that the predicted falling off of TWX/Telex traffic is a result of conversion to newer modes of character oriented message transmission and not to a reduction in intrinsic demand. The displaced demand may be expected to show up in estimates for other character oriented traffic.

The information contained in Figure 2.3-1 forms the basis for the projection of TWX/Telex traffic demand shown in Table 2.3-3.

TABLE 2.3-3. PROJECTED TWX/TELEX TRAFFIC DEMAND

	1980	1990	2000
1. Messages/Year	$151x10^6$	$145x10^6$	$90x10^6$
2. Traffic Demand (Bits/Yr.) (1)	$.87x10^{12}$	$.84x10^{12}$	$.52 x10^{12}$
3. L.D. Traffic Demand (Bits/Year≥200mi.)(2)	$.70x10^{12}$	$.67x10^{12}$	$.42 x10^{12}$

(1) 120 Words/Msg x 6 Char/Word x 8 Bits/Char = 5760 Bits/Msg. TWX uses 7 information bits/char while Telex uses 5. With roughly equal volumes between the two services, the average is 6 bits/char. Allowing 2 bits for start-stop, parity of other overhead functions of new transmission modes results in the 8-bit/character used.

(2) Eighty percent of TWX/Telex traffic is estimated to travel 200 miles or more.

2.3.2.2 Conventional FAX Traffic Demand

Facsimile dates back to 1843 when Alexander Bain, a Scottish clockmaker, first demonstrated the concept of electrical image transmission. Image transmission via wireless was successfully accomplished in 1908, and by 1910 a service for sending news pictures between Berlin, Paris and London was in operation. In the early 1930s, Associated Press demonstrated its international wire photo service, and special applications such as newswire, photo facsimile and weather facsimile were widespread by the 1960s. For the most part, however, facsimile was overshadowed by the less expensive, character-oriented transmissions of the telegraph industry. It is only since the late 1960s that business uses of facsimile have developed into a viable market. The result has been a growing component of traffic demand, referred to in this study as Conventional Facsimile Traffic to distinguish it from

other potential image traffic associated with new forms of electronic mail, or with page image transmissions required in support of remote teleconferencing.

The growth of traditional facsimile represents a continuing trend toward the use of the highly flexible image mode of document transfer with its ability to include signatures and handwritten annotations, variable type fonts, logos, and a wide range of graphic representations. Estimates of the magnitude of this trend, and forecasts of its future potential, can be based on the many surveys and projections provided by users, terminal manufacturers, and market research firms. These estimates, in the form of terminal population, carrier, revenue, and page count data, form the basis for the long range traffic demand projections presented later in this section.

There is an additional component of facsimile type image traffic which is not included here, but is reserved for discussion in the next section. This newer component is related to the evolution of electronic mail as a replacement for a major component of the document delivery services now performed by postal and courier services. Since the role of facsimile in this rapidly changing area is not fully defined relative to other cross elastic modes of electronic mail, traffic demand for this newer electronic mail component is only marginally reflected in terminal population. The projection and evaluation of future potential for advanced electronic mail uses of facsimile must therefore rely on other methodology such as that described in the next section.

There have been a number of surveys of facsimile terminal populations made in the course of recent market research studies. A summary of these is presented in Table 2.3-4, which displays eight sets of estimates for the installed FAX terminal base covering the years 1975 through 1985. In two of the sets of estimates, values (identified by asterisks) for the number of pages per year have additionally been presented.

As may be observed in Figure 2.3-2, which provides a graphical presentation of the different estimates, there is considerable variation (2:1) among the results. This occurs even when the estimates refer to populations for years prior to the date of the estimate and, therefore, represent what might be expected to be hard historical data. The reasons for this dispersion relate to the various methods of estimation used, the inclusion or exclusion of certain types of terminals such as the specialty newsphoto devices, and whether or not returns of leased units to the manufacturers are included. The results are, however, relatively consistent with respect to growth rate which averages about 18 percent per year.

TABLE 2.3-4. ESTIMATES OF INSTALLED FACSIMILE TERMINALS (THOUSANDS)

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Yankee Group - Market for a FAX store and forward system for ITT 1975	122	140	161	185	212	245					
A. D. Little - Impacts of Elect. Comm. Systems on U.S. Postal Service, Feb. 1977	121					240					485
Frost & Sullivan - FAX Equipment and Services in USA, May 1977			102	116	131	147	163				
Creative Strategies Inc. - The FAX Industry, Mar. 1978	100	107	120 122*	135 140*	152 162*	173 189*	198 229*	234 287*			
Telautograph Corp.- Quoted in Telecommunications, pg 77 May 1978				130							
Quantum Sciences - Office Tech. Strategy Program Vol. III 1978		146	175	208	247	290		388			
Yankee Group - Quoted in Computer Decisions, pg 36, Sept. 1978			146	188							
International Resource Devel. via Telecom. Steve Caswell, March 1979				195 210*		335			540		

*Pages/Year x 10^6

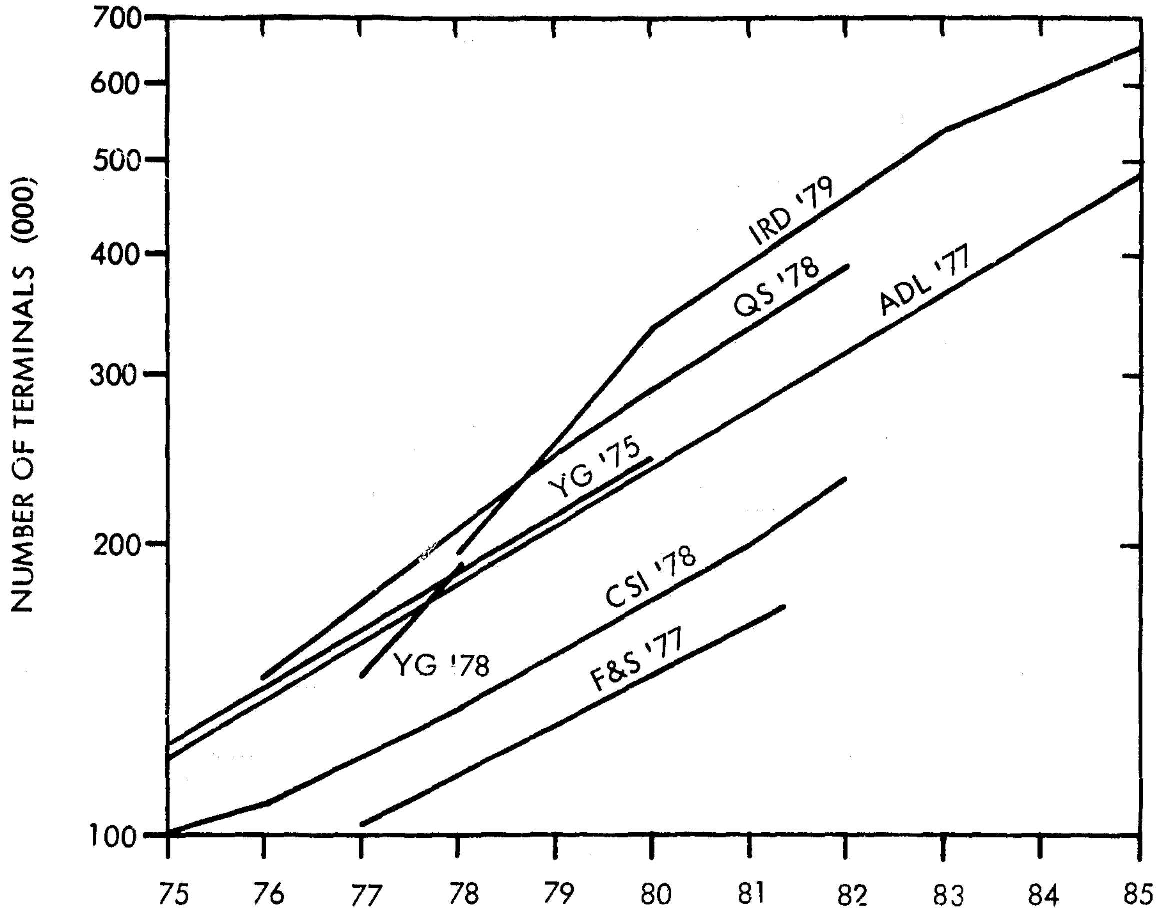

FIGURE 2.3-2. FACSIMILE TERMINALS INSTALLED BASE

The variability of the historical data base limits the accuracy that can be attained by projections extending from the base, but considering the uncertainties of the long range forecasting process itself, the limitations of the base line data are not inordinately significant.

The Quantum Sciences estimate for 1980 of 290,000 installed facsimile terminals offers a reasonable starting point, intermediate in value to other recently formed estimates, and based on a detailed survey of manufacturers.

In order to project terminal populations over the substantial time interval between 1980 and the year 2000, it is necessary to consider market penetration and possible saturation of the market.

Allowing 15 employees as the minimum size necessary for a typical business organization to justify the installation of a FAX terminal, and taking 100 million employees as a rough measure of the work force in the period in question, results in a maximum of 6.7 million groups having at least 15 employees. Thus, 6.7 million would be a logical long range upper limit that the installed terminal base might achieve, with perhaps one-third of this, or roughly 2.3 million, representing a practically achievable figure when due account is taken of the fact that many employees will, in fact, work in organizations too small to qualify or in activities with minimal telecommunications needs.

The above considerations provide broad guidance in estimating the compound growth rates that can reasonably be sustained over long periods of time. The growth rate in 1980 associated with the starting base of 290,000 terminals is 16 percent. Since 290,000 terminals represents only a small fraction of the 2.3 million potential, continued growth at the 16 percent rate is not unreasonable for the early 1980s. However, if that rate were to be sustained for any long duration, the saturation level would be reached in only 14 years. Some slowdown in growth rate is therefore to be expected during the first decade well before saturation is reached. For this reason an initial growth rate of 16 percent per year is accepted for the early 1980s, but it is coupled with a gradual decline in rate so that over the 1980-1990 decade the average growth is projected as 12 percent per year. A further slackening to 10 percent per year is projected for the 1990-2000 decade. The result of the 12 percent (1980-1990), followed by 10 percent (1990-2000) growth rate assumptions when applied to the starting base of 290,000 FAX terminals in 1980 results in a FAX terminal population for 1990 of 901,000 terminals, and for the year 2000 of 2,340,000 terminals.

In order to convert terminal population data to message volumes, estimates are required for the number of pages transmitted per year by a typical FAX terminal. Creative Strategies, Inc. (Ref. 2.3-2) cites survey results of 18.3 messages per week (952 per year) which they expect to grow to 22 per week (1144 per year) by 1980. The CSI figures cited in Table 2.3-4 for 1982 show a further growth to 1226 pages per terminal per year. IRD data presented in the same table shows 1076 pages per terminal per year growing to 3448 by 1988. The Yankee Group (Ref. 2.3-3) in a 1975 survey for ITT cited 6.33 pages per terminal per day (1582 per year) with a potential growth to 2600 pages per terminal per year. Their value of 6.33 pages per day was later downgraded to five (1200 per year) in a follow-up survey by ITT (Ref. 2.3-4).

For purposes of demand asessment under the present program, the value of 1300 pages per terminal per year has been adopted for the year 1980. For the years 1990 and 2000, a value of 2600 pages per terminal per year has been used, reflecting a two to one growth in usage as ongoing technology improves the convenience and reduces the cost of facsimile transmission. To further convert from pages per year to bits per year, a factor of 300,000 bits per page has been assumed. This is somewhat higher than the standards used for most of today's facsimile transmissions and reflects a desire on the part of users and manufacturers for a better quality page.

The results of the preceding discussion are summarized in Table 2.3-5 which shows terminal populations, pages per year, and traffic demand for 1980,1990 and 2000. Line 5 provides estimates for the percentage of traffic traveling 200 miles or more. The 1980 value of 35 percent is supported by ITT internal studies and is also consistent with current first class mail statistics supplied by the U.S. Postal Service (Ref. 2.3-5). Growth in this percentage to 50 and 60 percent by the years 1990 and 2000 respectively reflects increasing telecommunication usage to more distant sites as costs continue their trend toward distance insensitivity.

TABLE 2.3-5. CONVENTIONAL FAX USAGE

	1980	1990	2000
1. Installed Terminals	290×10^3	901×10^3	2340×10^3
2. Pages/Year/Terminal	1300	2600	2600
3. Pages/Year	$.377 \times 10^9$	2.34×10^9	6.08×10^9
4. Traffic Demand (Bits/Yr)	113×10^{12}	702×10^{12}	1820×10^{12}
5. Percent Long Dist. ($\geq$200 mi)	35%	50%	60%
6. L.D. Traffic Demand (Bits/Yr)	40×10^{12}	351×10^{12}	1092×10^{12}

2.3.2.3 Advanced Electronic Mail Systems - Traffic Demand

The increasing competitiveness of electronic modes of transmission relative to the physical transportation of paper documents is a developing trend with important consequences on future traffic demand. Related to this trend are the following projected developments:

(a) The diversion of a significant portion of the mail physically transported by the U.S. Postal Service to electronic modes.

(b) The emergence of common carrier networks such as SBS, ACS, XTEN and FAX-PAK specifically oriented to serving by electronic means the document distribution needs of business and government.

(c) The increasing deployment and use of Communicating Word Processors and other character oriented message terminals.

(d) An increase in the use of facsimile transmission, particularly with respect to intercompany applications, sparked by improved speed, convenience, and standardization.

(e) The institution of Office of the Future practices in a large segment of business and government installations.

The traffic demand discussed in this section is predicted to grow to significant magnitude in the coming decades, but has not yet become appreciable. It may utilize new types of terminals, require legislative and regulatory changes, and involve modifications of business practices and modes of personal communications. It is therefore separate and distinct from those elements of traffic based on the continued use (and moderate growth) of traditional terminal and communication modes, and must be added to the traffic projected for these traditional usages.

Some useful inputs for the estimation of the potential demand represented by electronic mail are provided by studies of the U.S. mail and estimates of that portion which is convertible to electronic transmission. Table 2.3-6 presents the results of a 1977 study by George Washington University (Ref. 2.3-6). The baseline data presented is for 1974 and shows 89 billion pieces of

TABLE 2.3-6. ESTIMATED POSSIBLE DIVERSION FROM MAIL STREAM (BILLIONS)

From	To	Type	1974 Volume		Volume Vulnerable to Diversion				Max. Poss. Diversion		
			First Class	Total	Very	Moderate	Slight	Non-Vuln.	1979	1984	1994
Business, Non-Profit, Govt.	Business, Non-Profit, Govt.	Transactions	6.6	6.6	6.6				1.9	5.9	20.5
		Correspond.	4.5	4.5	4.5				1.3	4.0	
		Solicitations	---	3.7		3.7			0.3	1.2	
		Books/Mags.	---	3.1				3.1	---	---	
		Packages	---	0.3				0.3	---	---	
	Households	Transactions	22.4	22.4		7.7	14.7		0.5	2.5	17.9
		Correspond.	2.4	2.4			2.4		---	---	
		Solicitations	2.6	17.7		8.7	9.0		0.6	2.9	
		Books/Mags.	----	9.1				9.1	---	---	
		Packages	----	0.9				0.9	---	---	
Households	Business, Non-Profit, Govt.	Transactions	6.7	6.7		6.7			0.5	2.2	8.7
		Correspond.	0.6	0.6			0.6		---	---	
		Resp. to Ads	1.3	1.3		1.3			0.1	0.4	
		Books/Pkgs.	---	0.2				0.2	---	---	
	Households	Letters	3.8	3.8		1.9		1.9	0.1	0.6	4.1
		Greet.Cards	4.8	4.8		1.8	3.0		0.1	0.6	
		Pkgs/Misc.	0.6	0.8				0.8	---	---	
		TOTALS	56.3	89.0	11.1	31.8	29.7	16.3			
		Percent		100%	13%	36%	33%	18%			

Source of Data: George Washington University

mail of all types, of which 11.1 billion (13 percent) are considered very vulnerable to conversion to electronic modes, and an additional 31.8 billion (36 percent) of which is considered moderately or possibly vulnerable. Essentially all of the mail considered vulnerable to diversion comes out of the 56.3 billion pieces of first class mail or the 21 billion pieces, primarily bulk advertising, that makes up third class mail. It is estimated that without diversion to electronic message services the mail volume would continue to grow by two percent per year, but that diversion is likely to result in a net decline of mail volume.

The George Washington University study also presents some estimates for the maximum possible diversion of mail for the years 1979, 1984 and (with caveats indicating that the estimate was beyond the limits of the method used) for 1994. These are presented in the right hand columns of Table 2.3-6. These estimates in some cases exceed the total volume vulnerable to diversion because the overall volume of mail, without diversion, was assumed to grow by two percent per year.

It should be emphasized that not all of the maximum possible diversion will necessarily be realized, and GWU's prediction is that only 30 to 50 percent will materialize. Furthermore, through 1984, and probably through 1990 as well, the only wide— spread means of electronic communications with households will be via the telephone. Thus, as far as data traffic is concerned, primary interest in the earlier years centers on the Business-to-Business category. (The Government and Non-Profit components are included in this category, but are not consequential.) Beyond 1990 some component of Household related traffic should be included to account for the impact of terminals in homes.

With respect to the sizable component of mail volume diversion indicated for 1979, there is little doubt that such incursions have already taken place. However, the effects of this have already been included in the business-to-business traffic estimated in other sections of this report as a result of terminal population counts, and should not be counted twice.

A similarly oriented 1977 study of the U.S. Mail by A.D. Little (Ref. 2.3-1) offers the result shown in Table 2.3-7. A diversion from first class mail volume to 14.8 billion pieces is estimated for 1985, amounting to about 20 percent of the volume considered.

TABLE 2.3-7. SUMMARY OF 1985 DIVERSIONS FROM FIRST CLASS MAIL
(Billions of Pieces)

Diversion due to Electronic Funds Transfer	6.2
Diversion due to other Electronic Systems	
Household Related	4.4
Business to Business	4.2
Total Diverted to Electronic Systems	14.8*
Estimated "Undiverted" FCM Total	73.5
Percent Diverted to Electronic Systems	19.7%

*An additional reduction of 2.2 billion pieces due to changes in business practices that reduce document transfer requirements is also predicted, but will not impact electronic data traffic.

Source of Data: A.D. Little

A third set of estimates is contained in a 1978 filing before the FCC by Xerox Corporation (Ref. 2.3-7). This filing estimates a 1976 volume of business—to—business first class mail of 16 x 10^9 pages intracompany, and 20.4 x 10^9 pages intercompany. It also estimates an additional 34.3 x 10^9 pages of intracompany private mail. The projections shown in Table 2.3-8 are developed in the filing.

It is difficult to compare these various estimates since they are not all on a common basis. They are in rough agreement with respect to document delivery volumes, but differ substantially with respect to the degree of penetration by electronic delivery methods.

The procedure used for forming traffic demand estimates for the present study is summarized in Table 2.3-9. Base line values for first class mail volumes were obtained from the George Washington University data presented in Table 2.3-6. Only those components of first class mail considered very vulnerable to diversion or moderately vulnerable were selected. This effectively limits consideration to business—to — business correspondence and transactions, plus a certain amount of transaction oriented traffic (chiefly bills and payments) between households and businesses.

TABLE 2.3-8. DOCUMENTS DELIVERED (Pages x 10^9)

	1975	1980	1985	1990
Intercompany	44.0	55.0	64.4	72.4
Intracompany	18.0	25.0	31.0	36.8
Total	62.0	80.0	95.4	109.2
Potential Demand for Elect. Delivery(1)	52.0	67.0	80.0	91.0
Realizable Market(2)	--	.015	2.05	7.4

1. 100% of Intracompany + 50% (approx.) of Intercompany.
2. For Elec. Comm. Sys. envisioned by Xerox in their filing

Source of Data: Xerox Filing

Government and Non-Profit Organizations are included in the business category, but are not very significant in terms of traffic. The base line values, starting point, and growth rate are indicated in Notes 1 and 2 of Table 2.3-9.

An additional component of demand relates to the substantial number of documents carried by truck and courier private mail systems. This is primarily intracompany traffic. The base line volume for this (Note 3) was taken from the Xerox filing (Ref. 2.3-7).

The base line values for the three major categories of traffic shown in Table 2.3-9 were extended by year at the growth rates indicated. Two percent per year is a currently accepted figure for first class mail and primarily reflects growing business and household populations. The slightly higher growth rate of three percent per year was used for private mail, reflecting business trends toward more paper oriented service and financial industries at the expense of the manufacturing sectors.

Within each category the penetration of Electronic Mail Systems was estimated. Penetration of the Business-to-Home and Home-to-Business category in 1980 was considered to be essentially zero. This does not mean that substantial diversion of mail volume has not occurred, but reflects the fact that the only electronic terminal in widespread home use in 1980 will be the telephone. Thus, aside from a small amount of data traffic via the touch tone pad, the data traffic emanating from and to homes

TABLE 2.3-9. PROJECTED TRAFFIC DEMAND
DUE TO ADVANCED ELECTRONIC MAIL SYSTEMS

		1980	1990	2000
Business to Business (1) First Class Mail Trans. and Corresp.	Mail Vol. (Pieces x 10^9) % Diverted to EMS Vol. to EMS (x10^9)	12.5 0.25% .03	15.2 25% 3.8	18.6 50% 9.3
Business to Home & (2) Home to Business FCM Transactions	Mail Vol. (Pieces x 10^9) % Diverted to EMS Vol. to EMS (x 10^9)	16.2 0% 0	19.7 5% 1.0	24.1 20% 4.8
Business to Business (3) Private Mail	Mail Vol. (Pieces x 10^9) % Diverted to EMS Vol. to EMS (x 10^9)	38.6 0.5% .19	51.9 60% 31.1	69.7 80% 55.8
Mail Volume Total (Pieces x 10^9)		67.3	86.8	112.4
Diverted to EMS Total (Pieces x 10^9)		.22	35.9	69.9
Percent Image/Character Modes (4)		90/10	50/50	20/80
Projected Image Mode Pages (x 10^9)		.20	18.0	14.0
Projected Character Mode Pages (x 10^9)		0.02	18.0	55.9
Image Mode Bits/Yr. @ 300,000 B/Pg. (x 10^{12}) (6)		(7) 60/0	5400	4200
Char. Mode Bits/Yr. @ 20,000 B/Pg. (x 10^{12})		(7) 6/0	360	1120

(1) Base Line 1974, Vol. 11.1 x 10^9 Pieces/Yr; Growth 2% per Annum

(2) Base Line 1974, Volume 14.4 x 10^9 Pieces/Yr; Growth 2% per Annum.

(3) Base Line 1976, Volume 34.3 x 10^9 Pieces/Yr; Growth 3% per Annum.

(4) Reflects growing conversion to more efficient character modes.

(5) Assumes one page per piece of mail.

(6) Assumes slightly better resolution than today's typical FAX.

(7) Already included in other 1980 traffic components. The value of zero is used when transferring these results to summary sheets to avoid double counting.

C-2

is negligible. Modest penetration may, however, be expected by 1990 (5 percent) with the growth of the home computing market and the associated availability of data terminals in the home. A still larger (20 percent) component is predicted for the year 2000, anticipating additional home data terminal growth and the possible development of home facsimile systems.

The largest penetration is expected in business-to business mail, particularly in the largely intracompany private mail, but also to an important degree for first class mail. Percentage penetration estimates are shown in Table 2.3-9.

The percentage of mail that is expected to be diverted to EMS is multiplied by the total volume predicted for each category to arrive at the volume in terms of pieces of mail per year. The contributions are summed to find the total volume of mail diverted to EMS for the years 1980, 1990, and 2000.

Since character oriented transmission modes use far fewer bits per page than image(facsimile) oriented modes, it is desirable to separate the total demand by mode before estimating data traffic in bits. The image mode, despite its relative inefficiency, offers a high degree of flexibility and the graphics capabilities for letterheads and signatures which are customary in today's business practices. As a result, in the earlier time frame between 1980 and 1990, image modes are expected to predominate. It is likely, however, that business practices will adapt to take advantage of the more efficient character oriented mode, and that communicating word processors and other electronic mail terminals of advanced design having character, or hybrid character/image, capabilities will become widespread. For this reason, character oriented traffic is predicted to become the predominant mode by the year 2000.

The percentage of penetration allocated to each of the basic transmission modes is then used in Table 2.3-9 to estimate the number of pages transmitted under the character and image modes for each year of the projection. These in turn are converted to bits by assuming 20,000 bits per character oriented page and 300,000 bits per image mode page to arrive at the final demand estimate.

The electronic mail traffic demand developed above will add to the total demand due to other data traffic components. However, as noted earlier, the demand estimates for 1980 are to a major extent already included in other demand estimates based on terminal populations. To avoid double counting of this component of traffic, the 1980 values for advanced electronic mail system demand is set equal to zero even though an appreciable diversion from the mail stream is estimated to have already taken place.

Table 2.3-10 summarizes the end results of the previous table and includes estimates of the percentage of traffic traveling 200 miles or more. The percent factor used for long distance derives from the previously cited U.S. Postal Service figures for first class mail.

TABLE 2.3-10. PROJECTED ADVANCED ELECTRONIC MAIL SYSTEMS TRAFFIC DEMAND SUMMARY

	1980 (4)	1990	2000
Elect. Mail-Image Mode (Bits/Yr) (1)	0	5400×10^{12}	4200×10^{12}
Elect. Mail-Character Mode (Bits/Yr) (1)	0	360×10^{12}	1120×10^{12}
Long Dist. Elec. Mail-Image (Bits/Yr) (≥ 200 mi) (2)	0	2700×10^{12}	2520×10^{12}
Long Dist. Elec. Mail-Char. (Bits/Yr) (≥ 200 mi) (2)	0	180×10^{12}	672×10^{12}
Total Long Dist. Electronic Mail Demand (≥200 mi) (3)	0	2880×10^{12}	3192×10^{12}

(1) From previous table.

(2) Currently 35% transmitted 200 miles or more growing to 50% in 1990 and 60% in 2000.

(3) Apparent decrease in demand in the year 2000 is due to switchover from Image modes to more efficient character oriented modes.

(4) 1980 Electronic Mail traffic included in other categories.

2.3.3 COMPUTER TRAFFIC DEMAND

This category of data traffic relates to traffic originating or terminating at a computer. It represents the substantial and growing traffic involved in the remote creation and accessing of data bases and the remote use of computing facilities. Thus, terminal inquiry/response traffic and remote time sharing each contribute to this traffic. Traffic that involves a computer only as a means of gaining access to communications facilities is, however, not considered part of this category. Thus, a message passing through a packet network node or a computer controlled message switching node is not necessarily considered computer traffic even though the message passes through one or more computers on the way to its destination.

As indicated in Table 2.3-1, Computer Traffic is discussed under the two headings of Terminal to CPU, and CPU to CPU traffic. Terminal to Terminal traffic is considered message traffic and has been included in the message traffic demand estimates discussed earlier.

2.3.3.1 Terminal/CPU Traffic Demand

Remote access to computers for data base related operations, or remote time sharing, is a well established activity with a body of historical data available. Statistics for terminal populations and near term growth rates have been published by several market research firms. A 1978 Quantum Science survey (Ref. 2.3-8) provides a detailed breakdown of terminals by type, and by user organization for the years 1976 through 1982. The data provided offers a suitable baseline for traffic demand estimation. The procedure followed in arriving at this estimate is outlined in Table 2.3-11.

The lefthand column lists those terminal types in the Quantum Science Corporation survey which are appropriate to the estimation of Terminal to Computer traffic demand. Other terminal types, such as factory data collection terminals, or point-of-sale terminals, have little role in generating traffic that might traverse satellite facilities and thus have been omitted. The next two columns in the table show Quantum Science's values for the 1976 and estimated 1980 populations for each terminal type, followed by the annual growth rate obtaining over the interval.

In many cases the growth rate shown is quite large, reflecting the emergence of new technology such as the conversion for non-programmable to "smarter" user-programmable terminals. Because of saturation effects, it is not reasonable to expect very large annual growth rates to prevail over the long periods

TABLE 2.3-11. INSTALLED TERMINALS AND TERMINAL/CPU TRAFFIC

	Terms. 1976 x 10^3 (7)	Terms. 1980 x 10^3 (7)	Growth Rate % '76-80	Growth Rate % '80-90	Growth Rate % '90-00	Terms. 1990 x 10^3	Terms. 2000 x 10^3	Bits/Yr. Per Term. x 10^6	Bits/Yr. 1980 x 10^{12}	Bits/Yr. 1990 x 10^{12}	Bits/Yr. 2000 x 10^{12}
Alphanumeric CRT Single Station, Non-Programmable	260	530	19.5	15	10	2143	5561	300 (1)	159	643	1668
Alphanumeric CRT Single Station, User Prog.On-Line	24	101	43.9	25	13	917	2920	200 (2)	20	183	580
Alphanumeric CRT Multi-Station, Non-Programmable	226	180	-5.8	-15	-15	35	7	400 (3)	72	14	3
Alphanumeric CRT Multi-Station User Prog.	85	425	49.5	15	10	1719	4460	270 (4)	115	464	1204
Alphanumeric CRT Single Station User Prog. Batch	39	178	46.2	15	10	719	1866	270 (5)	48	194	504
Teleprinter Non-Programmable	425	573	7.7	5	5	933	1519	540 (6)	309	504	820
Teleprinter User Program	51	195	39.8	20	12	1207	3749	540 (6)	105	652	2024
TOTALS	1110	2182				7673	20082		828	2650	6800

1. Typical Term./CPU Transact:
   Time Elapsed 51.1 Sec.
   Total Traffic 580 Char.
   Aver. Rate 11.35 Char/Sec.

Operator Input	Resp. Time	Comp. Transmits	Operator Reads	Dead Time
80 Char. @ 5 Char./Sec.		500 Char. @ 240 Char./Sec.	500 Char. @ 20 Char./Sec.	
16 Sec.	3 Sec.	2.1 Sec.	25 Sec.	5 Sec.

   At 10 Bits/Char. x 3600 Sec/Hr. x 3 Hrs/Day x 250 Days/Yr. = 300 Megabits/Terminal/Year.

2. Reduced to 200 Megabits/Terminal/Year to reflect communication processing in Smart Term.
3. Like 1, but usage increased to 4 Hrs/Day
4. Like 2, but usage increased + 4 Hrs/Day
5. Primarily data capture applications. 5 Char/Sec x 3600 Sec/Hr x 6 Hrs/Day x 250 Days/Yr x 10 Bits/Char. Results in 270 Megabits/Terminal/Year
6. 30 Char/Sec. x 3600 Sec/Hr. x 2 Hrs/Day x 250 Days/Yr x 10 Bits/Char = 540 Megabits/Terminal/Year.
7. Computer Equipment Strategy Program, Vol. III - Quantum Science Corp. 1978.

of time included in the present study. The columns headed "1980-1990' Growth Rate" and "1990-2000 Growth Rate" list the annual growth rates expected over this longer, two decade, period. These growth rates were used to project the population of each terminal type for the years 1990 and 2000. The results appear in the appropriate columns of Table 2.3-11.

To arrive at projections for data traffic demand, the average number of bits per year originated by each terminal is needed. There appears to be little published on this subject and, furthermore, the value may be expected to vary from ter minal type to terminal type. To arrive at estimates for these values a "typical" terminal/computer transaction was defined and the average data rate for this transaction was determined.

While many different transaction types may be postulated, and will in fact be used in terminal to computer transactions, an appropriately chosen typical transaction serves to define a data rate representative of, and reasonably close to, the average demand that will be experienced.

This approach is set forth in footnotes 1 through 6 of Table 2.3-11. Footnote 1 postulates a Terminal to CPU transaction typical of the data base access traffic commonly used by the alphanumeric, single station, non-programmable, CRTs identified in row one of the table. The transaction begins with a human input, assumed to be 80 characters long and limited in speed by the keyboard entry to about 5 characters per second. After a 3 second response time, which allows for communications turn-around, and queueing and processing delays, the computer responds by painting the screen with 500 characters of data (1/4 of a typical full screen). The elapsed time for this is 2.1 seconds. Twenty-five seconds are then allocated to absorbing the information presented, and an additional five seconds is assumed to elapse before the operator begins the next transaction. A total of 51.1 seconds is required for the complete transaction, during which 580 characters are transmitted in one direction or the other. Thus, the average speed during the transaction is 580 characters ÷ 51.1 seconds = 11.35 characters per second. Assuming that the average terminal is in use 250 days per year and 3 hours per day, and assuming 10 bits per character to allow for communications overhead, results in a total communications load of 300 megabits per terminal per year. This is the value used on line 1 of Table 2.3-11 to convert terminal populations to communications demand in bits per year for the years 1980, 1990 and 2000.

A slightly smaller conversion factor of 200 megabits per terminal per year is used on line 2 to reflect the reduction in communications workload afforded by the local processing

capabilities of the more sophisticated programmable terminals.

The non-programmable multistation CRTs listed on line 3 are similar in operation to those on line 1, but average usage is assumed to increase to four hours per day since these terminals are more likely to be employed in a production environment. Similarly, the programmable multistation CRTs of line 4 are equated with those of line 2 with daily usage increased from three hours per day to four hours per day.

The single station batch mode CRT terminals represented on line 5 are assumed to be used primarily in data capture applications. The total daily load is limited by the operator's data entry speeds of about 5 characters per second. The fact that data storage is used to accumulate batches of data which are stored and periodically transmitted at higher speeds does not affect the total number of bits transmitted per terminal. Allowing for 6 hours of productive use per day, the result is 270 megabits per terminal per year.

Lastly, an average communications load of 540 megabits per terminal per year is assigned to the teleprinter terminals appearing on lines 6 and 7. Transmission is assumed to be at 30 characters per second for an average of 2 hours per day.

The conversion factors discussed above are applied to their associated types of terminals to arrive at the data traffic estimates shown in the last three columns of Table 2.3-11 and summarized in Table 2.3-12. Traffic demand for 1980 totals 828 x 10^{12} bits per year, representing an average annual growth rate of 11 percent per year over the two decades projected. The long distance component shown in Table 2.3-12 is based on 25 percent of the traffic being transmitted 50 miles or more. This reflects the observed fact that the greater portion of terminals using telecommunications are linked to computers in the same city.

TABLE 2.3-12. TERMINAL/CPU TRAFFIC DEMAND

	1980	1990	2000
Traffic Demand (Bits/Yr) (1)	828×10^{12}	2650×10^{12}	6800×10^{12}
Long Distance Traffic Demand $\geq$200 mi (2) (Bits/yr)	165×10^{12}	530×10^{12}	1360×10^{12}

(1) From Table 2.3-11
(2) 20 percent of traffic estimated to travel 200 miles or more

2.3.3.2 CPU/CPU Traffic Demand

This component of traffic demand is one of the more difficult to deal with since little data has been published to support traffic projections. As in the previously discussed terminal/CPU situation, traffic which only incidentally involves computers (i.e., in passing through computer controlled switching nodes) is excluded from the CPU/CPU category. Only traffic originating at one computer, and terminating in another remote computer is considered under the present heading.

In projecting CPU/CPU traffic demand, two elements are considered to be the major contributors over the decades under study:

(a) Distributed Processing
(b) Electronic Funds Transfer

Each of these is discussed below.

(a) Distributed Processing

This important element of CPU/CPU traffic is fundamentally the result of data base adjustments. During the course of business and government activities, information is entered into local data bases. The mechanism of this transfer is diverse, but essentially results from human interface with the computer via terminals of various types. The data accumulated in local data bases, in a growing number of cases, is electronically transferred between CPUs so that it may be economically accessed by other users homing on their own local computers. The resultant transfers of data between computers is the basis of distributed processing and is expected to be a rapidly growing contributor to data traffic demand.

Since the original source of the data stored in the data base results from Terminal/CPU activity, it may be expected that CPU/CPU traffic will be proportional to Terminal/CPU traffic, but it is not immediately evident what the constant of proportionality should be. Unfortunately, distributed processing in the business environment is at an early stage of evolution and little information relating to this value exists. Some parallels, however, may be drawn with data relating to military systems. Military systems tend to be several years in advance of commercial technology and, therefore, potentially offer advanced views of future trends which may be suitably discounted for application in the commercial environment.

AUTODIN II is a worldwide, packet switched, data network which will support the data transmission requirements of

DoD and other government agencies. A study of its requirements lends some support to the present analysis. The prime contracts for the switching nodes of this military/government system have been issued and the network will be operating in the 1980s. In the course of developing the network specification, the user community was surveyed, and the network usage was projected in terms of the number and types of terminals, their line speeds, and the busy hour traffic expected from each terminal (Ref. 2.3-9). Certain of the "terminals", by virtue of their type designation and/or because of their high speed requirements, are identifiable as computers (other than those serving as the network packet switches themselves). The traffic expected to originate at these various terminals is summarized below.

TABLE 2.3-13. AUTODIN II TRAFFIC BY "TERMINAL" SPEED

Terminal Speed	Number of Terminals	Total Mbps in Busy Hour
56 Kbps	60	1.20
19.2 Kbps	60	.43
110 - 9600 Bps	1267	.37
TOTAL	1387	2.00

If it is assumed that all of the 56 Kbps traffic is computer to computer traffic, and that the remainder is Terminal to CPU traffic, the busy hour traffic in the network divides as follows:

CPU/CPU = 1.20 Mbps

Terminal/CPU = .80 Mbps

Ratio of CPU/CPU Traffic to Term. to CPU Traffic = 150%

Thus, for this advanced DoD network, each bit of internodal (long distance) terminal to CPU traffic is supported by at least 1.5 bits of internodal data transferred between computers. The ratio becomes even higher if some fraction of the 19.2 Kbps traffic is also ascribed to CPU/CPU data transfer. This is a remarkably high ratio and may be presumed to reflect some of the peculiarities of advanced military requirements. For the commercial and government (non-military) traffic of concern in the present study, a reduction in this 1.5:1 ratio by a factor of three is suggested, with this value being gradually approached as a value pertaining to the year 2000. In the discussion which follows, 50% of long distance Terminal to CPU traffic is used as the value for long distance CPU/CPU traffic in support of distributed processing

for the year 2000, 13% for 1990, and 5% for 1980.

Based on the previous discussion, Table 2.3-14 projects CPU/CPU traffic demand resulting from data base transfers related to distributed processing.

TABLE 2.3-14. CPU/CPU TRAFFIC DEMAND - DISTRIBUTED PROCESSING

	1980	1990	2000
Long Distance Terminal/CPU Traffic (1) (Bits/Year x 10^{12})	165	530	1360
Ratio of CPU/CPU Traffic (2) to Terminal/CPU Traffic	5%	13%	50%
Long Distance CPU/CPU Distributed Processing Traffic $\geq$200 mi. (Bits/Year x 10^{12})	8.25	70	680

(1) From table showing Terminal/CPU Traffic Demand
(2) Ratio grows to one-third of corresponding AUTODIN II value

The first line in this table shows the amount of long distance data traffic resulting from Terminal/CPU traffic as developed in the previous section. The second line shows the proportionality factor used to relate distributed processing CPU/CPU traffic to the Terminal/CPU demand. The last line extends these quantities to arrive at projections for the long distance CPU/CPU traffic demand projected in support of distributed processing.

(b) Electronic Funds Transfer

Electronic Funds Transfer systems have already reached sizable levels of activity, and the resultant demands on telecommunications capabilities are expected to continue to accelerate. The major portion of the communications demand associated with EFT results from the large volume of checks issued each year, and the clearing house operations necessary to transfer funds for these checks.

In their analysis of potential diversions from the mail stream, A.D. Little (Ref. 2.3-1) cites a number of estimates for the volume and growth of checks. A growth rate of 7 percent per year has been generally accepted, but the A.D. Little report indicates that over 80 percent of American households now have demand deposit accounts and that saturation effects are beginning to be evidenced. They refer to recent data indicating that

a linear rather than a compound growth curve due to this sector is appropriate.

Allocations are also made for Federal Government produced checks (7% of total in 1972), with particular reference to the major growth in Social Security, retirement, and health insurance payments. The resultant check volumes projected in the A.D. Little report, with extension to the year 2000, are shown in Figure 2.3-3. Estimates by other investigators tend to be somewhat higher, but appear not to have included possible saturation of the growth rate (Ref. 2.3-10).

It is assumed that one electronic transaction for each check is required to convey the necessary information. This is consistent with A.D. Little's detailed analysis showing that, on the average, one piece of first class mail results for each check written. The information conveyed (identification of account numbers, banks, amount to be transferred, etc.) is estimated at 1000 bits (Ref. 2.3-10).

Based on the previous discussion, the data traffic demand resulting from electronic funds transfer activities is projected in Table 2.3-15. It appears reasonable that CPU/CPU

TABLE 2.3-15. E.F.T. TRAFFIC DEMAND

	1980	1990	2000
1. Number of Checks per year ($\times 10^9$) (1)	36.3	50.1	63.8
2. Potential Traffic (Bits/Year $\times 10^{12}$) (2)	36.3	50.1	63.8
3. Percent Converted to EFT (3)	10%	60%	90%
4. EFT Bits/Yr $\times 10^{12}$ (@ 1000/Transaction)	3.6	30.1	57.4
5. L.D. CPU/CPU Traffic Demand for EFT (Bits/Yr. $\times 10^{12}$) $\geq$200 miles (4)	1.44	12	23

(1) From Figure 2.3-3.
(2) At 1000 bits per check.
(3) Reflects present activity level growing in response to widespread use of "Credit Card" funds transfer by 2000.
(4) Forty percent of traffic transmitted 200 miles or more.

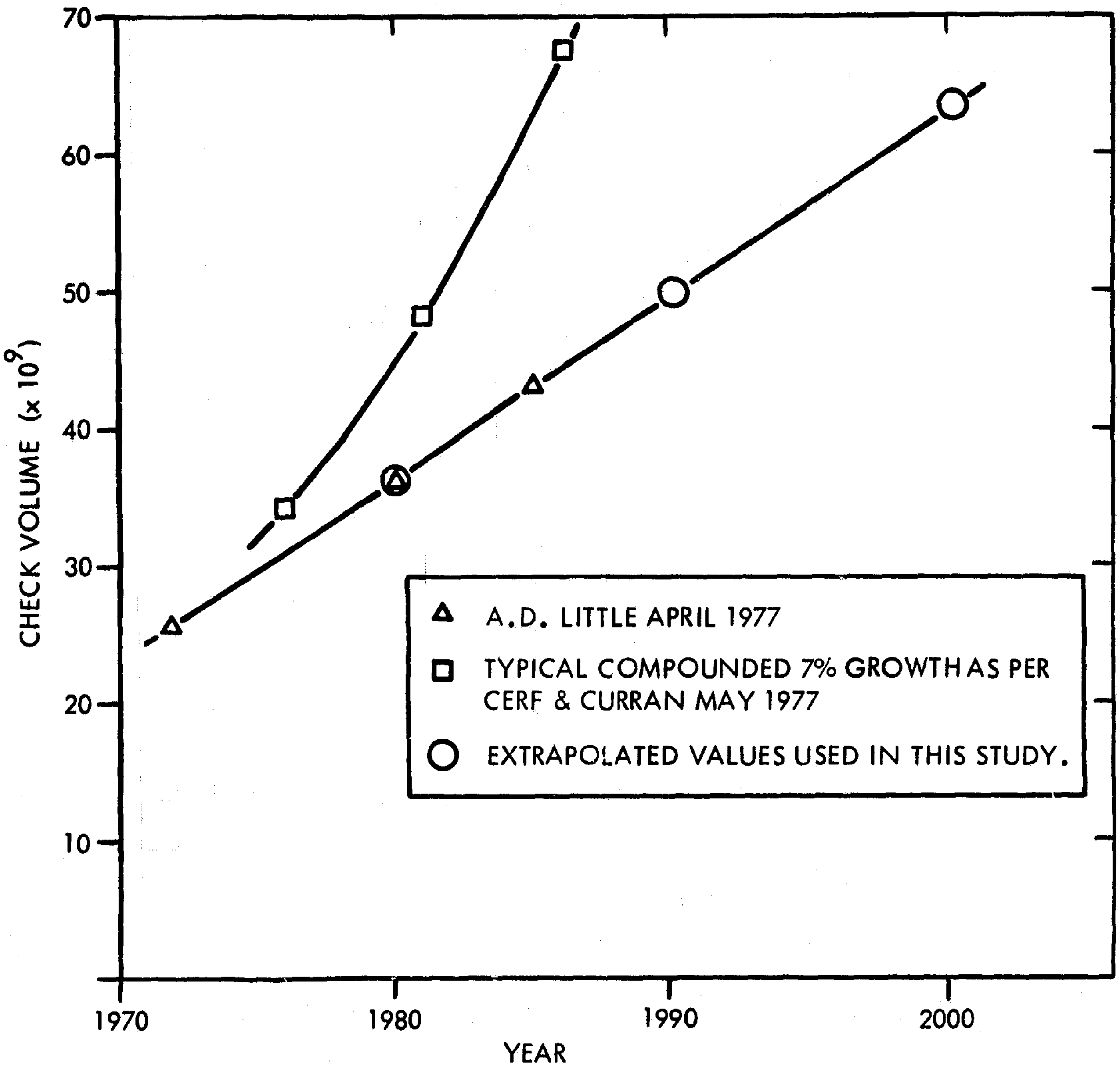

FIGURE 2.3-3. EXTRAPOLATED CHECK VOLUME

data base adjustments will have a larger intercity component than Terminal/CPU traffic, and line 5, therefore, allocates 40 percent of CPU/CPU to the 200 mile or greater category as opposed to the 20 percent allocated for Terminal/CPU traffic. Support for this factor also appears in Cerf and Curran (Ref. 2.3-10).

The two major contributions to CPU/CPU traffic demand are summarized in Table 2.3-16.

TABLE 2.3-16. SUMMARY OF CPU/CPU TRAFFIC DEMAND (200 Miles or More)

	1980	1990	2000
Long Dist. CPU/CPU Traffic Demand-Distrib. Processing (Bits per year)	8.25×10^{12}	70×10^{12}	680×10^{12}
Long Dist. CPU/CPU Traffic Demand-E.F.T. (Bits per year)	1.44×10^{12}	12×10^{12}	23×10^{12}
Total CPU/CPU Traffic Demand	9.7×10^{12}	82×10^{12}	703×10^{12}

2.3.4 NARROWBAND TELECONFERENCING TRAFFIC DEMAND

There appears to be little doubt that over the next decades the energy shortage will place restraints on travel for business purposes. Over the same time frame, technical improvements in telecommunications can be expected to offer increasingly attractive alternatives to travel. This situation is explored in greater detail in the sections of this report dealing with full-video teleconferencing and the discussion there is equally applicable to the present section.

The term "Narrowband Teleconferencing" refers to the use of audio/graphic telecommunications aids for the enhancement of remote conferencing. As opposed to full-video teleconferencing, which requires a wideband communications channel, narrowband teleconferencing takes place over a voice bandwidth circuit or the digital equivalent thereof. Thus, this section considers only those conferencing aids that occupy the standard four kilohertz telephone channel, or which require digital transmissions of about 56 kilobits per second or less. This includes high

speed image mode, as well as character oriented transmissions such as those produced by OCR scanners and tape typewriters. Freeze-frame television also is included in this category.

In a typical narrowband teleconference, the communicating parties converse over normal telephone channels, but on occasion support their conversation by transmitting one or more typed or handwritten pages, diagrams or pictures. Whether the information transmitted is finally converted to hard copy, or remains a volatile display, is not significant in terms of data traffic demand.

The pages to be transmitted may be sent over the channel used for the voice conversation or may utilize an auxiliary channel reserved for this purpose. If analog channels, similar to the four KHz channel commonly available today, are postulated, it will probably be necessary to interrupt the conversation for 20 seconds or more for each page sent in the image mode. This inconveniently long interruption may be expected to motivate the use of auxiliary channels for the graphics support function. On the other hand, if the conversation takes place over a 56 Kbps digitized voice channel, the transmission of a page takes only four to eight seconds and co-usage of the same channel for both conversation and graphics becomes an attractive and convenient alternative.

In those cases where an auxiliary channel is used for graphics, an important consideration is whether the auxiliary channel is kept active throughout the period of the conference, or whether it is dialed-up only when a page needs to be transmitted. Since a typical conference lasts an average of two hours, while the transmission of a limited number of pages (assumed to be ten per conference) requires only a few minutes, the demand for channel capacity obviously depends heavily on whether channel capacity is seized when needed or reserved throughout the conference. In evaluating traffic demand for graphics support in this section, it is assumed that transmission modes such as packet transmission, dial-up (with automatic dial assist), or some form of shared usage channel will be available to ensure efficient use of the channel. Thus, the analysis that follows projects demand by evaluating the number of bits necessary to accomplish the desired graphics support under the assumption that these bits will be efficiently packed into the necessary transmission facilities.

The procedure used to forecast narrowband teleconferencing demand parallels that used for full-video teleconferencing. That is, a certain segment of future business air travel is assumed to be displaced by telecommunications. Table 2.3-17 outlines the steps used in estimating traffic demand. Line 1 shows the number of enplanements projected for the years

TABLE 2.3-17. NARROWBAND TELECONFERENCING

	1980	1990	2000
1. Enplanements (1)	234×10^6	383×10^6	575×10^6
2. Business Enplanements @ 40% (1)	93.6×10^6	153×10^6	230×10^6
3. Conferences (Bus.Enplane. x .675) (2)	63.2×10^6	103×10^6	155×10^6
4. Conferences Potentially Replaceable by Audio/Graphic Teleconf. (@ 45%) (1)	28.4×10^6	46.4×10^6	69.8×10^6
5. Percentage Realized	1%	25%	50%
6. Number of Audio/Graphic Teleconf.	$.284 \times 10^6$	11.6×10^6	34.9×10^6
7. Pages per Year (@ 10 per Teleconf.)	2.84×10^6	116×10^6	349×10^6
8. Percent Image/Character Modes	95/5	90/10	75/25
9. Pages/Year Image Mode	2.70×10^6	104×10^6	262×10^6
10. Image Mode Bits/Yr. (@ 400,000 Bits/Pg.) (3)	1.08×10^{12}	41.6×10^{12}	104×10^{12}
11. Pages/Year Character Mode	$.142 \times 10^6$	11.6×10^6	87.3×10^6
12. Character Mode Bits/Yr.(@ 20,000 Bits/Pg.)	$.003 \times 10^{12}$	$.232 \times 10^{12}$	1.75×10^{12}
13. Teleconf. Hrs/Yr. (@ 2 Hrs/Conf.)	$.568 \times 10^6$	23.2×10^6	69.8×10^6
14. Teleconf. Hrs/Yr with Freeze Frame TV (4)	$.114 \times 10^6$	4.64×10^6	14.0×10^6
15. Bits/Yr for Freeze Frame TV (4)	7.88×10^{12}	320×10^{12}	968×10^{12}

(1) Technology Assessment of Telecom./Transportation Interactions, Vol. 2-SRI May 1977.

(2) Business Enplanements x (2.7 Conf./Round Trip) ÷ (2 Travelers) ÷ (2 Emplanements/Round Trip).

(3) Based on 85% office copy quality at 300,000 bits/page and 15% letter quality at 1,000,000 bits/page.

(4) Assumes that 20% of Audio/Graphic Conferences require additional capability for Freeze Frame TV on each of two 9.6 Kbps Channels (30-60 sec. refresh rate with image compression).

1980, 1990, and 2000 under the assumption that no replacement of travel by teleconferencing takes place. Forty percent of these enplanements are for business purposes (line two). Taking into account the fact that two enplanements are necessary for each round trip, that typically a conference requires travel by two participants, and that an average of 2.7 meetings are scheduled per trip, results in the number of business conferences shown on line three.

The Stanford Research Institute study referenced in Footnote 1 of Table 2.3-17 reports survey results showing that 45 percent of business travel could be satisfactorily replaced by suitable audio-graphic teleconferencing facilities. This factor is used on line four to arrive at the number of business conferences that are potential targets for replacement by narrow-band teleconferencing. The degree to which penetration of this potential market will take place depends on developments in national energy resource management as well as the prognosis for inexpensive but satisfactory teleconferencing aids. From both viewpoints, it appears that the future highly favors the teleconferencing approach, and, consequently, a relatively high penetration (50 percent) is projected for the year 2000. Half of this penetration (25 percent) is projected for the year 1990, and a modest one percent for 1980. These values are somewhat higher than those projected in the section dealing with full video conferencing, primarily because the much lower costs, and much higher availability, of narrowband facilities make this mode clearly cost-effective.

The realized percentages appearing on line five are extended to obtain the projected number of conferences per year using audio graphic teleconferencing for each of the years 1980, 1990, and 2000 (line six). These projections are, in turn, used to arrive at estimates for the number of pages per year transmitted as a result of narrowband teleconferencing. The values (shown on line seven) are based on an average of ten pages being transmitted in one direction or the other during the conference.

Both image mode and character oriented transmission modes may be used to deliver the pages needed. The image mode is expected to account for most of the page transmissions because it is adaptable to the transfer of a wide variety of documents on an ad hoc basis appropriate to the "face to face" interactions of a conference. The preparation of character—oriented mode information, on the other hand, is more likely to require pre-planning and the prior creation of tape or other electronic records for subsequent use in the conference. As communicating word processors become more common, and as transfer of data or messages from an electronic file directly to the recipient's screen becomes a

customary business practice, the fraction of teleconferencing pages transferred in character—oriented modes may be expected to increase modestly. For this reason, line eight shows the mix heavily favoring image modes in 1980, with only five percent being character oriented. By the year 2000, however, the character—oriented fraction is expected to increase to 25 percent of the total.

These factors are used to obtain the page counts for image and character mode transmissions shown on lines nine and eleven respectively. Lines ten and twelve use the factors indicated on the respective lines to convert to bits per year for each of the two modes.

Both because of facsimile's larger share of the total pages, and because the number of bits per page for image mode transmission is larger than for character—oriented pages, the traffic demand in terms of bits per year is dominated by the requirement for image mode transmissions which, by the year 2000, is projected to amount to 104 x 10^{12} bits/year.

The last three lines of Table 2.3-17 project traffic demand for freeze-frame TV. The number of conference hours per year devoted to audio/graphic teleconferencing (line 13) is derived from the number of teleconferences per year (line six) by assuming an average duration of two hours per conference. Any channel usage dedicated for the duration of a conference will require the number of channel hours indicated in line 13. This applies to the basic audio channel itself, any dedicated auxiliary channels used for graphics as discussed earlier, and if freeze—frame video is required, for this channel as well. It is likely, however, that if a freeze—frame channel is employed, it will also be used for the satisfaction of the graphics needs.

Line 14 postulates that 20 percent of the teleconference channel hours used will require an auxiliary freeze—frame TV channel in each direction. Assuming a 9.6 kilobits per second rate on these channels (which permits a 30 to 60 second picture refresh rate), results in the number of bits per year projected on line 15.

The traffic demand associated with freeze—frame TV is several times higher than that of the image and character oriented page modes projected on lines 10 and 12. This is primarily a reflection of the increased demand associated with full time occupancy of the channel as opposed to the occasional on—demand use postulated for the transmission of document pages. To place this in proper perspective, however, it should be noted that the large freeze—frame video demand represents only a fraction of the traffic that will be carried by the basic audio channels

established for the conferences (which, of course, are also held open for the duration of the conference). Thus, while the data requirements for teleconferencing, and for freeze-frame TV in particular, are significant, it should be kept in mind that the associated voice traffic is by far the dominant factor.

Since the projections developed in Table 2.3-17 are based on the displacement of long distance air travel, the resultant traffic demands are inherently long distance (200 miles or more). The pertinent results, obtained from Table 2.3-17, are summarized in Table 2.3-18.

TABLE 2.3-18. SUMMARY OF NARROWBAND TELECONFERENCING TRAFFIC DEMAND (200 MILES OR MORE)

	1980	1990	2000
Image Mode Traffic (Bits/Year)	1.08×10^{12}	41.6×10^{12}	104×10^{12}
Char. Mode (Bits/Year)	$.003 \times 10^{12}$	$.232 \times 10^{12}$	1.75×10^{12}
Freeze Frame T.V. (Bits/Year)	7.88×10^{12}	320×10^{12}	968×10^{12}
TOTAL (Bits/Year)	8.96×10^{12}	362×10^{12}	1074×10^{12}

2.3.5 SUMMARY OF DATA SERVICES TRAFFIC DEMANDS

Table 2.3-19 summarizes the demand for data services for the years 1980, 1990 and 2000 as developed in the previous pages. All of the traffic components projected are considered long distance. That is, they travel 200 miles or more and are not confined to a local city area. Totals are rounded to the nearest integer.

TABLE 2.3-19. SUMMARY OF DATA SERVICES TRAFFIC DEMAND (Bits per Year x 10^{12}, 200 Miles or More)

	1980	1990	2000
MESSAGE TRAFFIC			
TWX/Telex	0.7	0.67	0.42
Facsimile	40	351	1092
Electronic Mail-Image	0	2700	2520
Elect. Mail-Character	0	180	672
TOTAL MESSAGE TRAFFIC	41	3232	4284
COMPUTER TRAFFIC			
Terminal/CPU	165	530	1360
CPU/CPU - Distrib. Proc.	8.25	70	680
CPU/CPU - E.F.T.	1.44	12	23
TOTAL COMPUTER TRAFFIC	175	612	2063
NARROWBAND CONFERENCING			
Image Mode	1.08	41.6	104
Character Mode	.003	.232	1.75
Freeze Frame TV	7.88	320	968
TOTAL NARROWBAND/ TELECONFERENCING	9	362	1074
TOTAL TRAFFIC DEMAND	224	4206	7421

2.4 CONVERSION OF VOICE, VIDEO AND DATA DEMAND TO DIGITAL UNITS

For convenience in summing the traffic demand projected for voice, video and data, it is desirable to convert the previously developed projections from the application specific units (call-seconds, circuits, bits, etc.) used in the previous discussion, to a common unit of measure. Since the satellites that will be available in the time frame under consideration are likely to provide digital transmission facilities, a digital unit of measure, such as terabits per year, is appropriate. This section develops the methodology and conversion factors required for this conversion to terabits per year.

At the same time, this section takes into account the efficiency with which each communications application may be expected to utilize the transmission facilities. Thus, for example, appropriate bandwidth compression factors for various components of video traffic are introduced to allow the expression of demand in terms that reflect the true requirements of each video application for satellite capacity. Similarly, in the voice area, applications requiring full time private line service are weighted appropriately to account for the consumption of satellite capacity during hours in which the channel may be idle, but is nevertheless reserved exclusively for the user. With respect to data traffic, due account is taken of possible losses of transmission efficiency resulting from line overheads and/or interactive human-computer response times, as appropriate to each application.

Thus, the converted values arrived at in this section express potential demand in a form which reflects relative magnitudes of each of the components and permits meaningful aggregation of the components to arrive at the total potential demand. The units used (terabits per year), in addition to being commensurate with each other, lend themselves conveniently, in later sections, to the additional consideration of peaking factors and capture ratios necessary to relate potential annual demand to required peak hour satellite capacity.

2.4.1 VOICE SERVICES

Voice service demand as discussed earlier in Section 2.1 is divided into the four subcategories shown in Table 2.4-1.

TABLE 2.4-1. SUBCATEGORIES OF VOICE SERVICE DEMAND WITH CORRESPONDING APPLICATION SPECIFIC UNITS

Subcategory	Units
Message Toll Service (MTS) Business	Call-Seconds per Year
Message Toll Service (MTS) Residential	Call-Seconds per Year
Wide Area Telephone Service (WATS)	Call-Seconds per Year
Private Line Service	Nominal Duplex 4 KHz Voice Circuits

Demand for the first three of these is described in terms of offered traffic in call-seconds per year as determined by a count of the annual number of messages and the average duration of a message. Demand for private lines, however, is described in Section 2.1 in terms of a fundamentally different unit, 4 KHz voice channels. To the telephone carrier or satellite system, the traffic on these private lines is of no significance since time slots on the digital facility must be reserved whether traffic is present or not.

In order to convert call-seconds per year (the units used for MTS and WATS) into a digital traffic equivalent, it is simply necessary to multiply by the voice digitization rate. The voice digitization rate assumed in this study is the standard Bell System T1 telephone carrier rate of 64 Kbps per voice channel. This rate is rapidly becoming standard in North American and overseas commercial telephone systems. The 64 Kbps rate includes the per channel signalling overhead. More sophisticated voice digitizing techniques are currently available which provide greater digital compression, for example, 9600 bps Continuous Variable Slope Delta (CVSD) modulation, but these techniques are predominantly limited to use by the military and other specialized users because of cost, complexity, and quality considerations. There is negligible use of this equipment in commercial carrier trunking systems at present, and the difficulties inherent in obtaining widespread acceptance of new standards will probably keep the 64 Kbps channel predominant over the time frame projected.

Calculation of terabits per year for private lines is accomplished by first converting to call-seconds and then proceeding as before. Each line is assumed to be a full period (i.e., 24 hours per day) leased-line which generates 24 x 3600 = 86,400 call-seconds per day. Having converted from private lines

to call-seconds, terabits per year are calculated by multiplying by the per channel digitization rate of 64 Kbps. An additional factor of two is applied to account for the need for a trunk in each direction for the usual full duplex operation.

Table 2.4-2 presents voice traffic demand in terabits per year for the years 1980, 1990 and 2000 as obtained by applying the conversions discussed above to the Voice Traffic Demand projection presented in Table 2.1-21.

TABLE 2.4-2. VOICE TRAFFIC DEMAND IN TERABITS/YEAR (Greater than 200 Miles)

	1980	1990	2000
MTS Residential	81,000	197,000	378,000
MTS Business	88,000	230,000	502,000
WATS	160,000	369,000	572,000
Private Lines	230,000	605,000	1,441,000
Total	559,000	1,401,000	2,893,000

Peaking factors and other conversions, required to estimate actual satellite channels needed, are discussed in Section 6.3.

2.4.2 VIDEO SERVICES

Video service demand, as discussed in Section 2.2, is divided into the five subcategories shown in Table 2.4-3.

TABLE 2.4-3. SUBCATEGORIES OF VIDEO TRAFFIC AND APPLICATION SPECIFIC UNITS

Subcategory	Units
Network TV	Video Channels (1)
CATV (Channels)	Video Channels (1)
Videoconferences	No. of Teleconferences per year (2)
Education	Video Channels (1)
Health & Public Affairs	Video Channels (3)

Notes: 1. Video channels are expressed in simplex video channels leased full period for the year.

2. Each video conference requires a duplex channel. The average length per conference is two hours. Conversion to simplex channels requires multiplying by 2.

3. Simplex video channels used 40 hours per week.

The term "video channel" as used in the context of Table 2.4-3 refers to a transmission facility capable of serving the end user independent of any considerations of compression. Also, as seen from the table, video conferencing requirements are given in terms of the number of conferences projected for the year rather than in channels. It is necessary, therefore, to convert both video channels as used for Network TV, CATV, Education, and Health and Public Affairs, and video conferences to a common basis, terabits/year. In order to accomplish this, the average anticipated bit rate for video transmission in each subcategory must be defined for each benchmark year. Based on a review of the literature, and interviews with leading video equipment suppliers, the video compression ratios shown in

Table 2.4-4 have been projected for the years 1980, 1990 and 2000. These compression ratios reflect a weighted average of the mix of video equipment types anticipated for each time frame.

Table 2.4-4 indicates that full video without compression will be used almost exclusively for each subcategory in 1980. The basic bit rate assumed for full video without compression is 42 Mbps. This is a nominal rate since various video manufacturers use slightly different rates. Compression ratios as high as 14 to 1 are possible for the year 2000 for use in the less critical video applications such as videoconferencing. However, demands for higher quality images, as users become more sophisticated, must also be considered, resulting in the weighted value of seven to one predicted in Table 2.4-4.

TABLE 2.4-4. PROJECTED VIDEO COMPRESSION RATIOS(1)

Service	1980	1990	2000
Network TV	1:1	1:1	2:1
CATV	1:1	2:1	3:1
Videoconference	1:1	6:1	7:1
Educational Video	1:1	6:1	6:1
Health and Public Affairs	1:1	5:1	7:1

(1) Relative to a basic rate of 42 Mbps for a simplex full video channel.

Conversion from video channels to terabits per year for the Network TV, CATV, and Educational Video categories is as follows:

Terabits per year = Video channels (from Table 2.2-17)
x 8760 hours per year
x 3600 seconds per hour
x 42×10^6 bits per second (basic video channel rate)
÷ Compression factor (from Table 2.4-4)
÷ 10^{12} bits per terabit

The conversion in the case of the Health and Public Affairs category is essentially the same except that the number of hours of usage per year is assumed to be 40 hours per week x 52 weeks per year, or 2080 hours per year.

For the Videoconferencing category, the conversion is as follows:

Terabits per year = Teleconferences per year (from Table 2.2-17)
x 2 simplex lines per teleconference
x 2 hours per teleconference
x 3600 seconds per hour
x 42 x 10^6 bits per second (basic video channel rate)
÷ Compression factor (from Table 2.4-4)
÷ 10^{12} bits per terabit

The results of these conversions, when applied to the information in Table 2.2-17, are presented in Table 2.4-5. Additional conversions, required to estimate actual satellite channels needed, are discussed in Section 6.3.

TABLE 2.4-5. VIDEO TRAFFIC DEMAND IN TERABITS PER YEAR (Greater than 200 Miles)

Service	1980	1990	2000
Network TV	13,200	15,900	10,600
CATV	46,400	33,100	26,500
Videoconference	3,000	83,700	267,800
Education TV	19,900	36,400	110,400
Health and Public Affairs	0	1,600	2,200
Total	82,500	170,700	417,500

2.4.3 DATA SERVICES

The Data Services category, as indicated in Section 2.3-1, is divided into the following subcategories:

MESSAGE	COMPUTER	TELECONFERENCING
TWX/Telex	Terminal/CPU	Teleconf. - Image
Fascimile	CPU/CPU-Distrib.Proc.	Teleconf. - Character
Elect.Mail-Image	CPU/CPU-E.F.T.	Freeze Frame TV
Elect.Mail-Char.		

Since data traffic is naturally in digital form, conversion to terabits per year requires only that appropriate efficiency factors be applied. As discussed below, the efficiency factors will differ for each of the types of Data Service under consideration. Efficiency as used in this context is a measure of the ratio of the amount of information to the communications capacity required to transfer that information.

In many cases, the efficiency factor is quite low resulting in a considerable multiplication of the required capacity. Access from keyboard terminals to remote computers illustrates the high degree of inefficiency typical of many practical data transfer applications. Generally, when a terminal accesses a computer through dial-up facilities, a full voiceband channel is seized for the duration of the session. Similarly, in terminal/CPU applications using private lines, a voiceband channel is usually occupied by the terminal or terminals sharing that line and furthermore that voiceband channel is reserved full time whether or not data is actually being transferred.

If the needed voiceband channels are derived digitally, as is most probable for advanced satellite systems, the digital equivalent of these channels will be required. This forecast assumes that over the time frame projected, the 64 KBPS rate (128 KBPS for full duplex) widely used as the digital equivalent of a voice channel in the T-1 Carrier System will prevail.

Thus, remote computer access applications typically will occupy communications links capable of transferring thousands of bits per second but, because of human interaction times may actually transfer information at rates averaging only a few bits per second. The consequent high degree of inefficiency results in a very large multiplication of the service demands associated with these applications and this has been reflected in the demand estimates for data serves presented in the forecast for 1980. Network approaches which avoid the high degree of inefficiency have begun to emerge, chiefly in the form of packet networks and similar specialized data network offerings of various carriers. Such approaches can be effective in improv-

ing efficiency by factors in the order of 100 to one. This forecast assumes that by 1990, one-third of the terminal/CPU applications will benefit by the availability of such facilities and that by the year 2000 this will increase to 60 percent.

Even with these sizeable portions of traffic travelling via packet, or other relatively efficient means, the overall efficiency of data traffic remains low throughout the forecast period. The efficiency factors used for each Data Service subcategory are shown in Table 2.4-6 and discussed in the following paragraphs. These factors, when applied to the basic data volumes presented in Table 2.3-19, result in the Data traffic demand projected for each benchmark year shown in Table 2.4-8.

TABLE 2.4-6. DATA SERVICES EFFICIENCY FACTORS

SERVICE	1980	1990	2000
TWX/Telex	.01	.1	.2
Fascimile	.15	.2	.25
Electronic Mail-Image	---	.5	.5
Electronic Mail-Character	---	.4	.4
Terminal/CPU	.0015	.002	.0035
CPU to CPU-Dist. Proc.	.007	.01	.02
CPU to CPU-EFT	.1	.2	.4
Teleconference-Image	.25	.25	.25
Teleconference-Character	.25	.25	.25
Freeze Frame TV	.5	.5	.5

a) TWX/Telex

TWX and Telex are low speed switched message services using teletypewriters. The 100 to 1 efficiency factors indicated for 1980 results from the predominant use of dial-up circuits to connect the two user ends in a real-time operating mode. The use of manual keyboards to transmit messages causes the information rate to be much lower than the line capacity rate. Punched paper tape helps to alleviate this inefficiency somewhat, but this mode cannot always be used. Increases in efficiency are projected for the years 1990 and 2000 as a result of the increasing use of packet switching modes. Packet switching protocols permit the elimination of inefficiency during pauses in information transfer, but introduce some overhead inefficiency for framing, addressing, error protection and signalling information.

While store-and-forward modes are presently offered by Western Union, and are expected to increase in volume, the basic circuit from the viewpoint of satellite transmission remains real-time since the user requires a real-time channel to transmit to, or receive from, the remote store-and-forward switch.

b) Facsimile

In 1980, nearly all facsimile traffic will be transmitted on either dial-up telephone circuits or private lines. The years 1990 and 2000 will see the increased use of more efficient packet modes of transmission and, therefore, an increase in efficiency is reflected for these years. This increase in efficiency is not dramatic, however, since present day facsimile transmission is already relatively efficient from a transmission point of view. A typical analog facsimile terminal transmits each 8-1/2" by 11" sheet in four to six minutes. The newer digital facsimile terminals achieve subminute page rates and utilize most of the available circuit bandwidths. Some inefficiency, however, results from the use of a 4-wire channel on the trunk facility (contributing a factor of 0.5), the time taken to coordinate the two circuit ends prior to the transmission of each sheet, and line overhead requirements. As newer facsimile machines appear on the market, an increasing number will contain automatic coordination and sheet feed mechanisms, thereby increasing efficiency. The transmission mix assumed includes some private line service since other factors such as cost and convenience dictate the use of this mode. The use of private lines for the transmission of facsimile, however, generally is less efficient than dial service when typical idle periods of the line are considered.

c) Electronic Mail - Image

The predominant generator of electronic mail traffic in the image mode will be the Postal Service or similar users of high volume bulk image mode transmission. The use of full period simplex circuits is postulated to handle these transmissions and, because of the high traffic density and the acceptability of store and forward modes, relatively high efficiency may be expected. Some image-type electronic mail traffic, however, will be generated by users with lesser volumes, and may be expected to be less efficient.

The overall composite efficiency factor projected for 1990 and 2000 also considers down-time due to machine failure, work shift breaks, and other normal human and machine caused inefficiencies. The efficiency for 1980 has not been estimated since data traffic under the Electronic Mail category has been included in other categories.

d) Electronic Mail - Character

Electronic mail transmission in the character mode is expected to be slightly less efficient than the image mode. This results from the greater use of this mode by office-to-office

word processors for electronic "mailbox" applications. That is, as communicating word processors become more prevalent in the office environment of the future, increased use will be made of the word processor to directly transmit letters and memoranda. This method of communication, however, is basically of lower volume in comparison with the bulk Postal Service type traffic and will have significant components using real-time and interactive modes. The overall efficiency for character mode Electronic Mail has therefor been projected at a slightly lesser efficiency than that for the image mode.

e) Terminal/CPU

While Terminal/CPU traffic demand, as projected in Table 2.3-19 is of substantial size, it is not the largest component in the Data Traffic Category. Nevertheless, because the transmission modes for this component tend to be very inefficient, the transmitted traffic in terabits per year required to satisfy Terminal/CPU demand becomes by far the most significant element in the forecast for Data Traffic. The estimation of the efficiency factor for this type of traffic is therefore discussed in some detail.

In a typical application, a keyboard/CRT Terminal and/or hard copy printer is connected via a data link to a remote computer, and used for such varied purposes as entering sales orders, checking inventory, and making airline reservations, bank transfactions and credit checks. The communications channel, capable of relatively high bit rates, stands idle most of the time while the operator types at the keyboard, waits for a response, reads the response from the screen, and prepares for the next action. Furthermore, there is an additional contribution to inefficiency as a result of line protocols, error checking, synchronization, etc.

In some applications, multiplexing, polling, or other line disciplines are used to improve efficiency on long distance lines but these are not always cost justified and generally are primarily applicable only to that portion of the traffic that uses private lines.

The most important contributor to increased efficiency for interactive Terminal/CPU traffic is expected to be packet switching which is projected to play an important role in the years 1990 and 2000. Nevertheless, the composite efficiency of this component of traffic is, and will remain, low causing Terminal/CPU traffic to be the major component of traffic demand.

The first column of Table 2.4-7 shows the assumptions used in estimating for each year, the composite efficiency factors used for Terminal/CPU traffic. Dial-up traffic of this type is assumed to have an efficiency of 0.5 percent. Private line traffic has basically the same characteristics, but, allowing for some amount of multiplexing, etc., to improve efficiency while allowing for a large amount of idle time which has the opposite effect, an overall value of one-sixth of the dial-up line efficiency has been assigned. Packet network traffic has been assigned the relatively high value of 50 percent.

TABLE 2.4-7. EFFICIENCY FACTORS FOR TERMINAL/CPU TRANSMISSIONS

		Percent of Total		
	Efficiency	1980	1990	2000
Dial Network	.005	50	33	20
Private Line	.005÷6	50	33	20
Packet Network	.5	0	33	60
Average Efficiency		.0015	.002	.0035

The last three columns in this table show the percentage of traffic of each type forecast by year. Negligible packet traffic has been assumed for 1980 but this type of traffic grows to 33 percent by 1990 and 60 percent by the year 2000. The remaining traffic is equally divided between the less efficient dial-up and private line modes.

The last line of Table 2.4-7 presents the weighted average efficiency. Despite the large component of packet traffic the efficiency factor remains low, reaching only 0.35 percent by the year 2000.

The consequence of these low efficiencies is that this component of data traffic will play an important role in projected traffic demand.

f) CPU-to-CPU, Distributed Processing

In this communications mode, data and processed results are transferred directly between computers with little or no human intervention. This subcategory, therefore, is basically

more efficient than terminal-to-CPU traffic since much of the interactive human element is removed. Inefficiencies, however, result from protocol overhead and delays, and various computer activities such as calculations, sortings, record location, etc., which cause idle time on the data link. Distributed processing traffic, therefore, is projected to be more efficient than terminal-to-CPU traffic, but still relatively inefficient compared to most other categories.

g) CPU-to-CPU Electronic Funds Transfer

The primary component of this traffic subcategory is exemplified by the clearing house operations of the banking community. Financial organizations have been the leaders in converting to electronic operation due to the costs of handling the large volumes of "paper" inherent to the industry. Because of the volumes involved, and the acceptability of store and forward modes, the transmission efficiency of this subcategory is expected to approach that of electronic mail.

h) Teleconferencing-Image

The data traffic which supports teleconferencing has been divided into three subcategories. The first, teleconferencing-image, refers to the use of facsimile type terminals on voice grade lines to transfer graphics information during a teleconference. In this mode, a separate dial-up line (or the teleconferencing voice line itself) is used to send the graphics information. The efficiency of terminal usage is basically the same as that projected for the facsimile subcategory; however, the line efficiency is projected to be somewhat better because of the predominant use of dial-up facilities without the inclusion of a significant component of less efficient private line usage.

i) Teleconferencing-Character

This mode makes use of character-oriented terminals (e.g., keyboard, OCR) for the transmission of text material on voice grade lines during the teleconference. Although more efficient than the image process in terms of information content conveyed for the bits transmitted, there is no difference in efficiency in data transmission.

j) Freeze Frame TV

The efficiency of transmissions on a freeze frame TV teleconferencing channel is high since the ratio of information bits to total bits transmitted is nearly unity. (Image compression has been separately accounted for.) The 50 percent

efficiency factor shown in Table 2.4-6 results from the conversion of the two-wire local circuit to the four-wire transmission system on the trunk facility. The use of a freeze frame digital television system operating at the equivalent capacity of the voice channel during the period of the teleconference has been assumed, with any potentially spare capacity available on the voice grade channel being used, to allow an increase in the frame rate.

The data traffic demand projected in Table 2.3-19 may be modified to account for the efficiency with which each component is transmitted by dividing the values shown in Table 2.3-19 by the efficiency factors presented in Table 2.4-6. The results are summarized in Table 2.4-8 which projects data traffic demand for distances greater than 200 miles in terabits per year with appropriate values for the efficiency of transmission applied. The dominant component is Terminal/CPU traffic. While the basic information volume needed for other components of Data Traffic such as Electronic Mail, Facsimile or Freeze Frame TV are equal to or greater than the volume of information transmitted in Terminal/CPU transactions, the higher efficiency of the other components reduces their final impact relative to the latter.

TABLE 2.4-8. DATA TRAFFIC DEMAND IN TERABITS PER YEAR (Greater than 200 Miles)

	1980	1990	2000
MESSAGE TRAFFIC			
TWX/Telex	70	7	2
Facsimile	267	1,755	4,370
Electronic Mail-Image	0	5,400	5,040
Electronic Mail-Character	0	450	1,680
Total Message Traffic	340	7,610	11,000
COMPUTER TRAFFIC			
Terminal/CPU	110,000	265,000	389,000
CPU/CPU-Distrib. Proc.	1,180	7,000	34,000
CPU/CPU-E.F.T.	14	60	58
Total Computer Traffic	111,000	272,000	423,000
NARROWBAND TELECONFERENCING			
Image Mode	4.3	166	416
Character Mode	0.01	0.9	7
Freeze Frame TV	15.8	640	1,940
Total Narrowband Teleconferencing	20	818	2,360
TOTAL TRAFFIC DEMAND	112,000	280,000	437,000

2.4.4 SUMMARY OF VOICE, VIDEO AND DATA DEMAND IN DIGITAL UNITS

The traffic demand for Voice, Video and Data services has been expressed in consistent units (terabits per year) in Tables 2.4-2, 2.4-5 and 2.4-8. These values take into account the efficiency factors and compression ratios expected to prevail in each of the forecast years.

Table 2.4-9 summarizes the results presented in the Tables mentioned above. All of the projected traffic demand is long distance (nominally 200 miles or more) and is considered a suitable target for transmission via satellite channels. Voice traffic remains the dominant component throughout the forecast period.

TABLE 2.4-9. SUMMARY OF VOICE, VIDEO AND DATA TRAFFIC DEMAND IN THOUSANDS OF TERABITS PER YEAR (Greater than 200 Miles)

	1980	1990	2000
VOICE	559	1401	2893
VIDEO	83	171	418
DATA	112	280	437
TOTAL	754	1852	3748

Growth rates for all three services are comparable even though demand for video and data services, by most measures, is expected to increase at considerably higher rates than demand for voice. The reason for this is that over the time frame of this study the efficiency of video and data transmission is projected to improve to a greater extent than that of voice. As a result, in terms of demand for average throughput capability of the communications plant as projected in Table 2.4-9, growth rates for voice, video and data over the 20 year forecast period all fall in the seven to nine percent per annum range.

The last line in Table 2.4-9 presents the totals by year for all three services. These represent the yearly throughput required of the long distance communications plant. For those pricing approaches which depend solely on the volume of bits transmitted, the information in the table provides a measure proportional to anticipated revenues. The values shown, however, do not translate directly to required satellite transponder capacity since factors such as peaking effects and the percentage of traffic captured by satellite communications media,

remain to be accounted for. These additional factors are considered in Section 6 of this report where the material developed in the present section is used to arrive at demand for satellite transponders, and to examine the influence on demand of communications reliability and real-time vs deferred traffic modes.

2.5 GEOGRAPHICAL DISTRIBUTION OF TRAFFIC

This section considers Voice, Video, and Data traffic as a function of the distance it is transferred, both in terms of the total volume of traffic that is transferred, and in terms of the density of the traffic per unit area. It also discusses the relationship between city size and traffic volume, and provides a geographical model in the form of maps showing traffic density over the United States.

2.5.1 DISTANCE DISTRIBUTION OF TRAFFIC

The distance over which traffic is transferred depends on community of interest patterns that exist within the United States. Many of the communication traffic components considered in this study may be expected to follow distance distributions typical of long distance telephone traffic. MTS Voice traffic is clearly of this type, and so also are some components of Data traffic. Teleconferencing, however, may be expected to follow distance distribution patterns more like those pertaining to airline traffic and the message traffic distance distribution finds its parallel in the distribution of First Class Mail.

The overall distribution of communications traffic vs distance may be determined for the Voice, Video, and Data categories by selecting, for each of the subcategories involved, the most closely allied basic community of interest. The appropriate distance distribution can then be applied to each subcategory and, to the extent that significant differences exist, weighted averages for Voice, Video, and Data traffic can be determined.

The first step in accomplishing this requires the determination of those distance distributions which logically may be applied to each of the subcategories. Three separate distributions were investigated as discussed below.

The first distance distribution investigated pertains to those traffic components which are essentially telephone-like in nature. Data was obtained from AT&T sources (Ref. 2.5-1) showing the number of originating and terminating toll calls by numbering plan area for a typical 24-hour period in 1978. From this, a 40 by 40 city pair traffic matrix (see Section 2.5.2) was constructed and subjected to computer analysis.

The computer analysis was used to sort the traffic into several distance bands and derive the percentage of busy hour toll calls associated with each band. This analysis was repeated for each of the years 1980, 1990, and 2000 under the assumption that the traffic for each city pair increases in proportion to

the projected population growth for the cities involved. Results for those toll calls that are transmitted 200 miles or more are presented in Table 2.5-1.

TABLE 2.5-1. DISTRIBUTION OF BUSY HOUR CALLS BEYOND 200 MILES

Distance D in Miles	Percent of Calls Transmitted Distance D			
	1978	1980	1990	2000
200	100.0	100.0	100.0	100.0
250	90.7	90.6	90.0	89.4
300	83.9	83.6	82.7	81.5
500	66.4	65.9	64.1	62.2
1000	40.4	40.0	38.5	37.0

Despite sizable changes in population over the 22-year period, very little impact on the distance distribution is observed. Within the limits of accuracy of this estimation, therefore, the values shown for 1978 may be accepted as approximately typical of all years in the time frame of this study. These values are plotted as crosses in Figure 2.5-1 along with other points representing the distance distribution of other communities of interest as discussed below.

The points plotted as circles in Figure 2.5-1 apply to First Class Mail and provide a second distance distribution applicable to message traffic with particular reference to electronic mail. The data is derived from 1978 U.S.P.S. statistics (Ref. 2.3-5).

The third set of points, plotted as squares, represents the distribution of airline passenger origin/destination mileage, as obtained from data compiled by the CAB and published by the ATA. Again, the data is for 1978 and has been normalized to include only those trips which are over 200 miles long. This distribution is most applicable to teleconferencing which may be expected to exhibit community of interest patterns similar to those represented in air travel statistics.

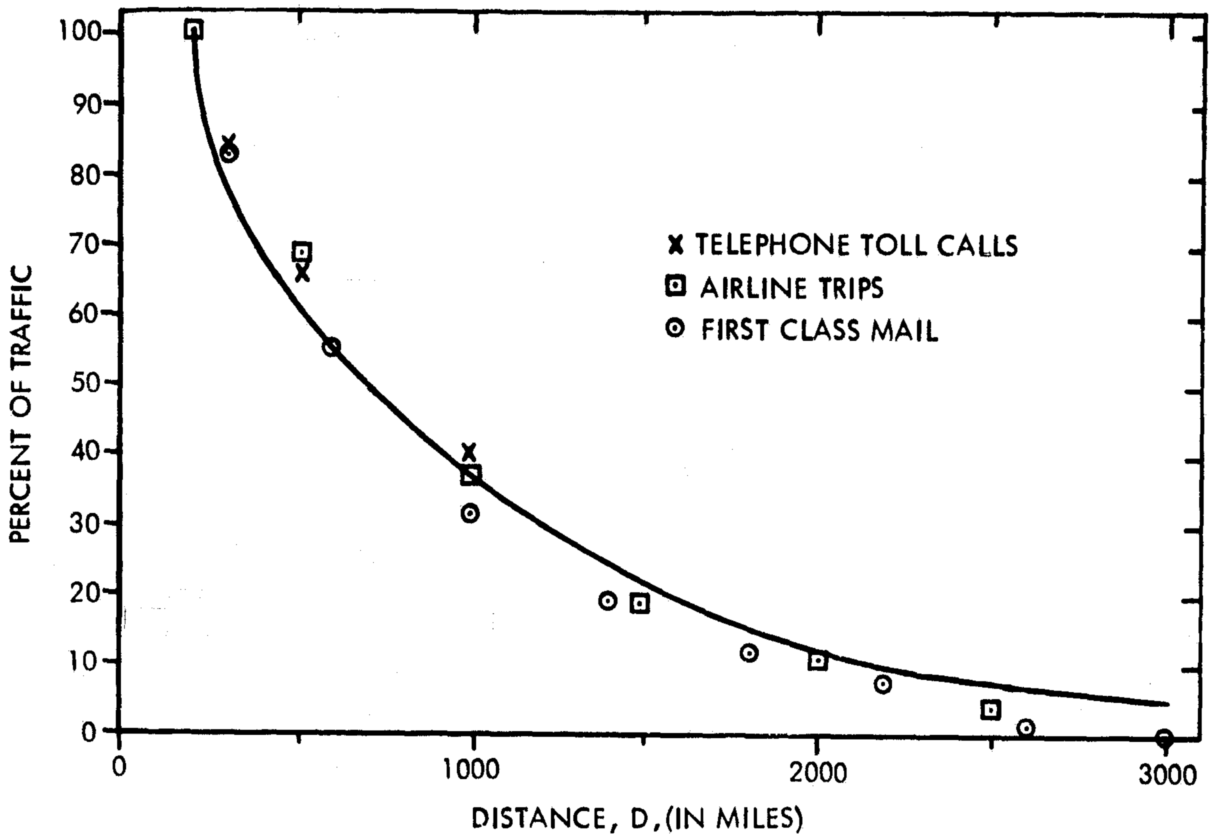

FIGURE 2.5-1. PERCENT OF TRAFFIC EXCEEDING 200 MILES TRAVELING A DISTANCE GREATER THAN D

The three distributions plotted in Figure 2.5-1 are remarkably similar considering the diversity of the communities of interest represented. The single curve illustrated provides a reasonable approximation to all three distributions. The equation of this curve is:

$$T = 100e^{-\frac{D}{1000}}$$

where T is the percent of traffic beyond 200 miles that travels D miles or more. Based on this empirical curve, 50 percent of the traffic most suitable for satellite transmission (i.e., that transmitted beyond 200 miles) travels more than 700 miles and 37 percent travels more than 1000 miles.

Since a single distribution provides a good approximation to the three communities of interest represented by toll telephone, air travel, and first class mail statistics, it is reasonable to assume that no significant difference will be found in the distances traveled by the various communications components that are logically related to these distributions.

Thus it may be concluded that, to a first approximation, voice and data traffic and many of the subcategories of video traffic, follow roughly the same distance distribution. Furthermore, it appears from the previously discussed insensitivity of the distance distribution of telephone toll traffic to future population shifts that this distribution will not change significantly over the time frame of the study.

Network TV, CATV, and some of the other components of video, however, depart from the distance distribution discussed above. These network-oriented subcomponents of the Video Services category require a relatively small number of wideband channels originating in specific major metropolitan areas. These channels are used in a broadcast mode to reach a widely dispersed set of users. While Network TV and CATV demand is of significance circa 1980, the rapid growth of Videoconferencing soon dominates video demand. As a result, with the possible exception of 1980, the bulk of video as well as voice and data traffic is predicted to follow the distance distribution illustrated in Figure 2.5-1.

2.5.2 TRAFFIC VOLUME AS A FUNCTION OF CITY SIZE

This section provides estimates of the magnitude of traffic volume as a function of city size. It also presents demographic data describing the number of cities of each size category and the distribution of population within these cities.

To investigate the relationship between traffic volume and city size, data showing the number of toll calls for each Numbering Plan Area (NPA) was obtained from AT&T call completion reports (Ref. 2.5-1). The toll calls for those NPAs constituting an SMSA were aggregated and translated to busy hour calls for each of 40 selected SMSAs. The population of each of the SMSAs was also determined. These SMSAs were selected as typical candidate sites for satellite earth station installation on the basis of size, wide geographic dispersion, and existing satellite and feeder facilities. Table 2.5-2 lists the 40 SMSAs, their populations, and the busy hour toll calls originating and terminating in each.

Figure 2.5-2 shows busy hour calls vs population for the SMSAs listed. The solid line represents the best mean square fit to the data points which pass through the origin. The line has a slope of 19.65 indicating that approximately 20,000 toll calls enter or leave an SMSA per million of population.

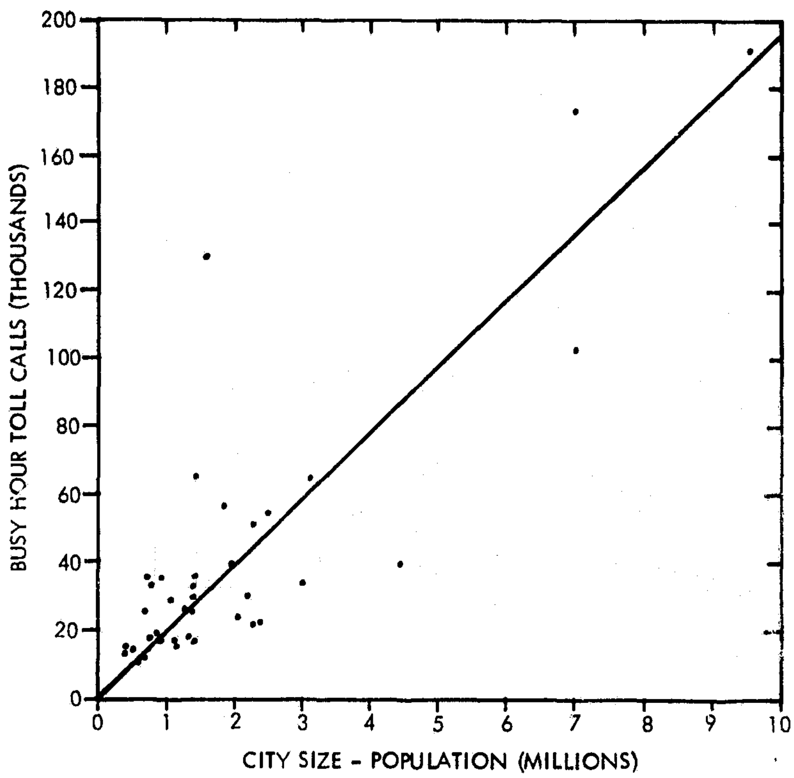

FIGURE 2.5-2. BUSY HOUR TOLL CALLS VS CITY SIZE

TABLE 2.5-2. BUSY HOUR CALLS AND POPULATION OF FORTY SMSAs

SMSA		BUSY HR. TOLL CALLS (THOUSANDS)	POPULATION (MILLIONS)
1.	New York	190.9	9.56
2.	Chicago	103.3	7.02
3.	Los Angeles	174.1	6.99
4.	Detroit	39.5	4.42
5.	San Francisco	64.9	3.14
6.	Washington	34.3	3.02
7.	Boston	56.6	2.89
8.	Dallas	54.8	2.53
9.	St. Louis	32.6	2.37
10.	Pittsburgh	21.9	2.32
11.	Houston	51.7	2.29
12.	Minn./St. Paul	24.1	2.01
13.	Cleveland	39.6	1.97
14.	Atlanta	56.3	1.79
15.	San Diego	130.1	1.53
16.	Miami	66.0	1.44
17.	Denver	36.6	1.41
18.	Milwaukee	29.5	1.41
19.	Seattle	33.1	1.41
20.	Cincinnati	26.1	1.38
21.	Tampa	26.1	1.35
22.	Buffalo	17.6	1.33
23.	Kansas City	18.2	1.29
24.	Phoenix	30.1	1.22
25.	Indianapolis	16.4	1.14
26.	New Orleans	16.5	1.09
27.	Portland	29.1	1.08
28.	San Antonio	35.3	.93
29.	Louisville	17.4	.88
30.	Memphis	19.2	.87
31.	Birmingham	33.6	.79
32.	Nashville	35.5	.75
33.	Oklahoma City	17.5	.74
34.	Jacksonville	26.0	.69
35.	Syracuse	11.6	.65
36.	Charlotte	16.9	.59
37.	Omaha	10.4	.57
38.	Tucson	15.7	.44
39.	El Paso	15.0	.42
40.	Albuquerque	14.8	.39
	TOTAL	1689.9	78.21

Figure 2.5-3 shows the number of cities in each of six size categories, ranging from small urban centers to very large metropolitan areas. The data is developed from Census Bureau information for 1975 as summarized in the Statistical Abstract of the United States. Additional demographic data is presented in Figure 2.5-4 which shows how the urban population is distributed with respect to city size. Cities with populations of 10,000 or more contain a total of 109.3 million people (1975 data) or 51 percent of the total population. Of these 109.3 million, roughly half live in cities of 100,000 or more and 15 percent live in cities with populations greater than one million.

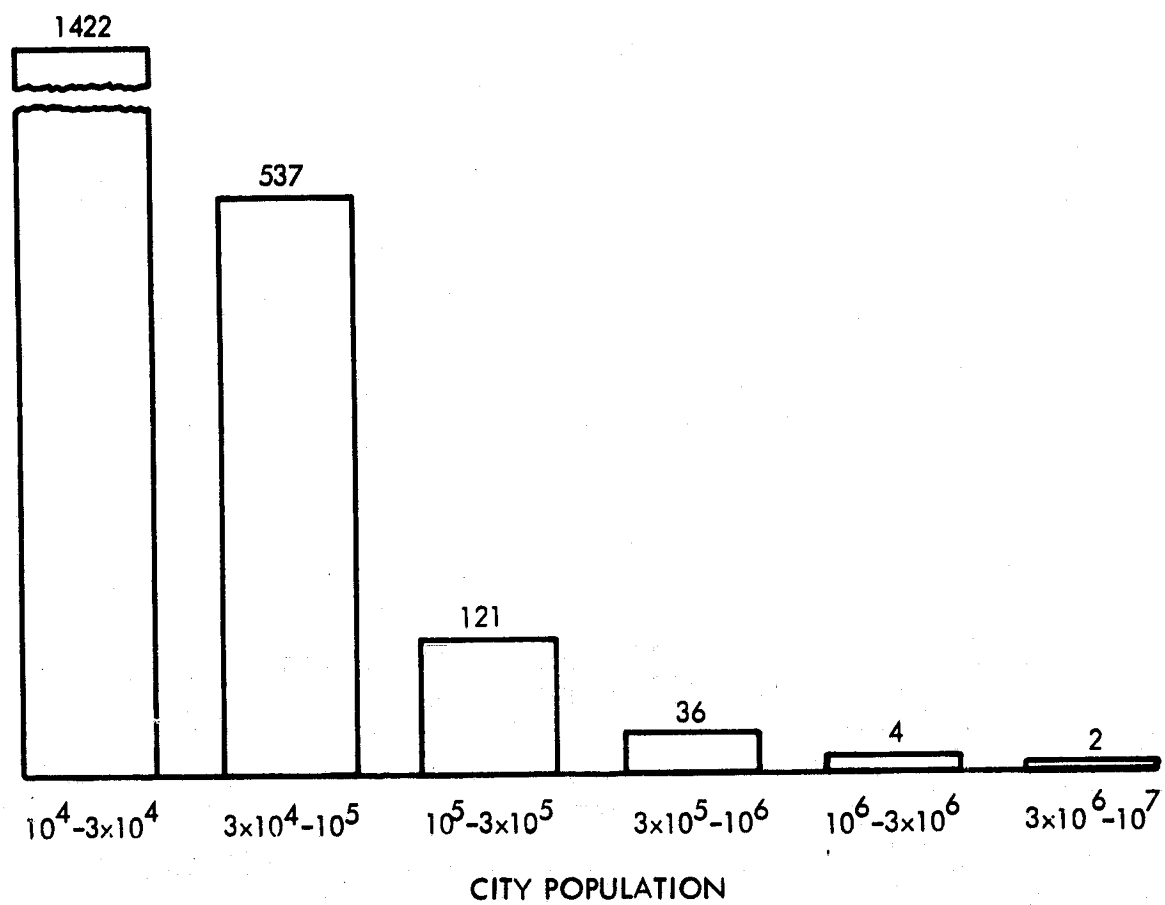

FIGURE 2.5-3. NUMBER OF CITIES IN EACH CITY SIZE CATEGORY

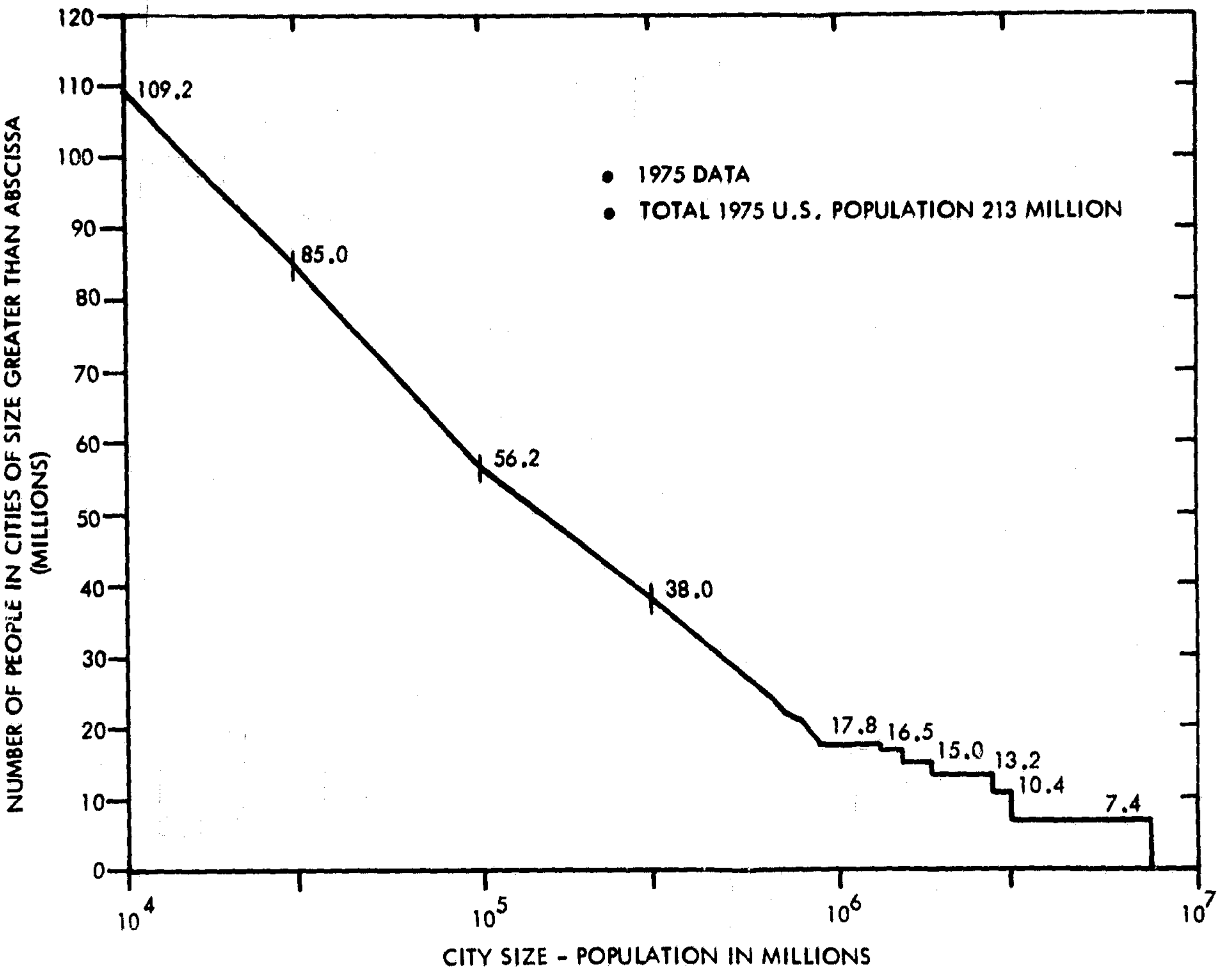

FIGURE 2.5-4. DISTRIBUTION OF POPULATION BY CITY SIZE

These results are also presented in Figure 2.5-5 as a bar chart showing the percentages of the population falling into the six city size groupings discussed earlier. Under the assumption that, over a wide mix of cities with varying characteristics, population is the basic determinant of traffic, the population percentages in Figure 2.5-5 apply equally well to traffic. Thus, Figure 2.5-5 provides an indication of the distribution of traffic (as well as population) as a function of city size.

A detailed breakdown of the total traffic for each communications service (Voice, Video, and Data) by city size is difficult to arrive at since cities in the same size category can vary widely in their characteristics. Cities with primary emphasis on agricultural, manufacturing, residential, or commercial activities will be found well represented in most of the size

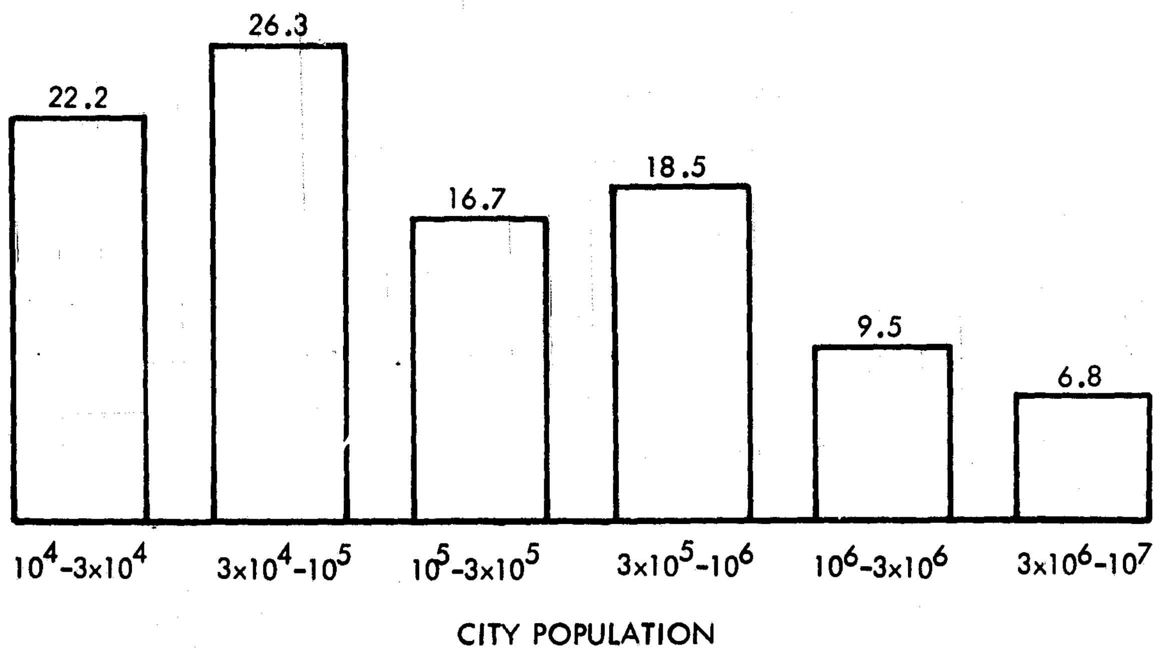

FIGURE 2.5-5. PERCENT OF POPULATION (OR TRAFFIC) BY CITY SIZE FOR CITIES WITH POPULATIONS ABOVE 10,000

categories. However, when averaged over many cities in each size category, there is a definite trend toward a business orientation and away from residential as city size increases.

This trend toward a business-oriented character for the larger cities may be roughly quantified by examining the ratio of business telephones to total telephones for a large number of cities. Data of this type was developed from the Statistics of Communications Common Carriers (Ref. 2.1-9) and is plotted in Figure 2.5-6 for 359 cities ranging in size from 37,000 to over seven million in population. In larger cities, business telephones represent 33 percent of the total, but as the city size decreases, the ratio of business telephones also decreases, reaching an extrapolated value of 20 percent for cities as small as 10,000 in population.

The circles shown in Figure 2.5-6 indicate the ratio of business to total telephones typical of each of the six city size categories used in Figure 2.5-5. These values, when multiplied by the percent of total traffic shown in Figure 2.5-5

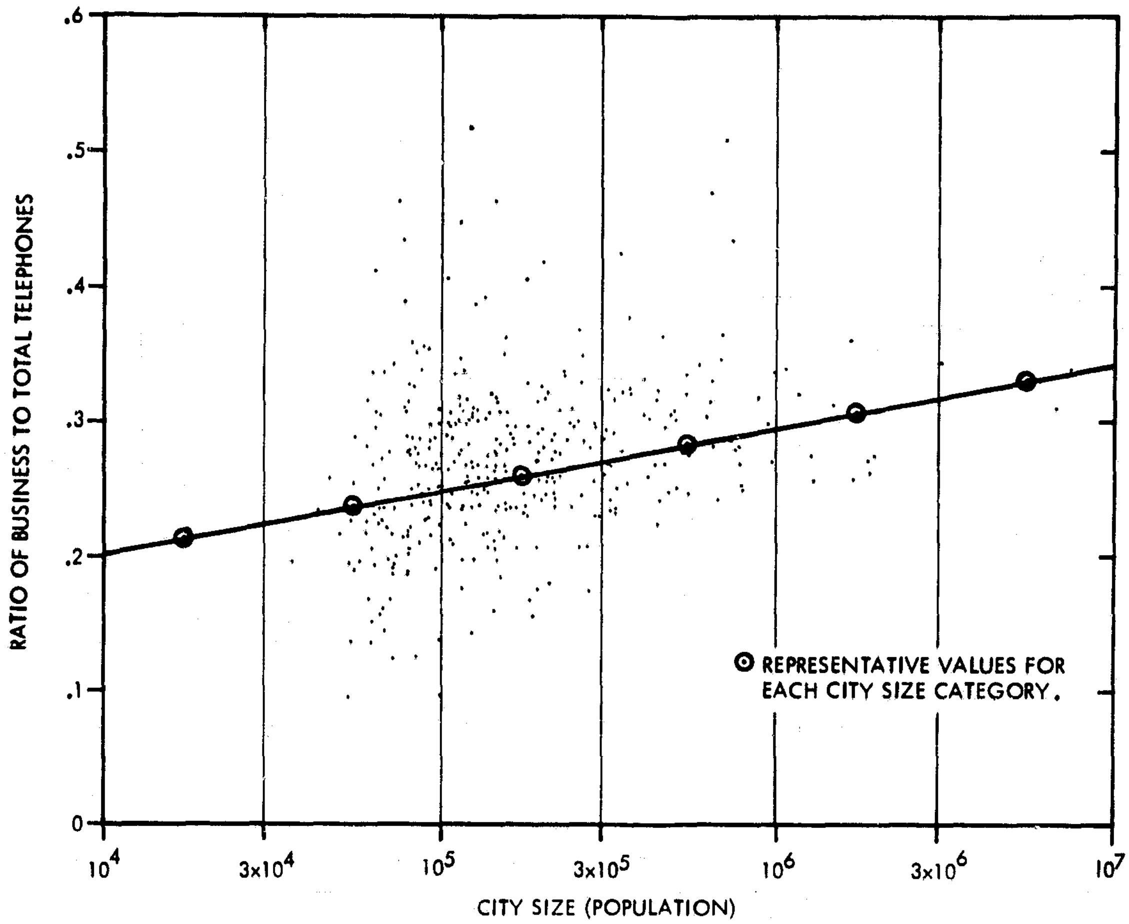

FIGURE 2.5-6. RATIO OF BUSINESS TO TOTAL TELEPHONES VS CITY SIZE

permit a comparison of the relative magnitudes of business-oriented traffic from category to category of city size. The relative values, normalized to represent 100 percent of business traffic, are presented in Figure 2.5-7. The complements of the ratios developed in Figure 2.5-6 (i.e., one minus the ratio) play a similar role with respect to the comparison of residential traffic from city size category to category. This result, normalized in this case to total 100 percent of residential traffic, is presented in Figure 2.5-8.

The sorting of residential and business-oriented traffic by city size category, as shown in Figures 2.5-7 and 2.5-8, may be approximately correlated with the service categories of Voice, Video, and Data used elsewhere in this report. The business traffic distribution of Figure 2.5-8 may be used as a model for almost all of the Data traffic and for the Video components with the exception of Network TV and CATV. These two Video

exceptions will be primarily confined to specific large metropolitan areas rather than being generally distributed over the United States.

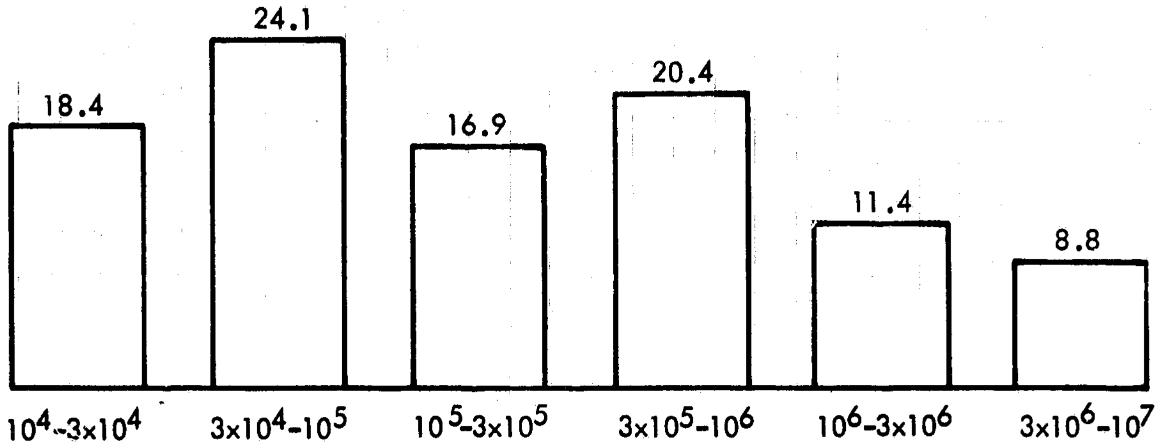

FIGURE 2.5-7. PERCENT OF BUSINESS TRAFFIC BY CITY SIZE (FOR CITIES WITH POPULATIONS ABOVE 10,000)

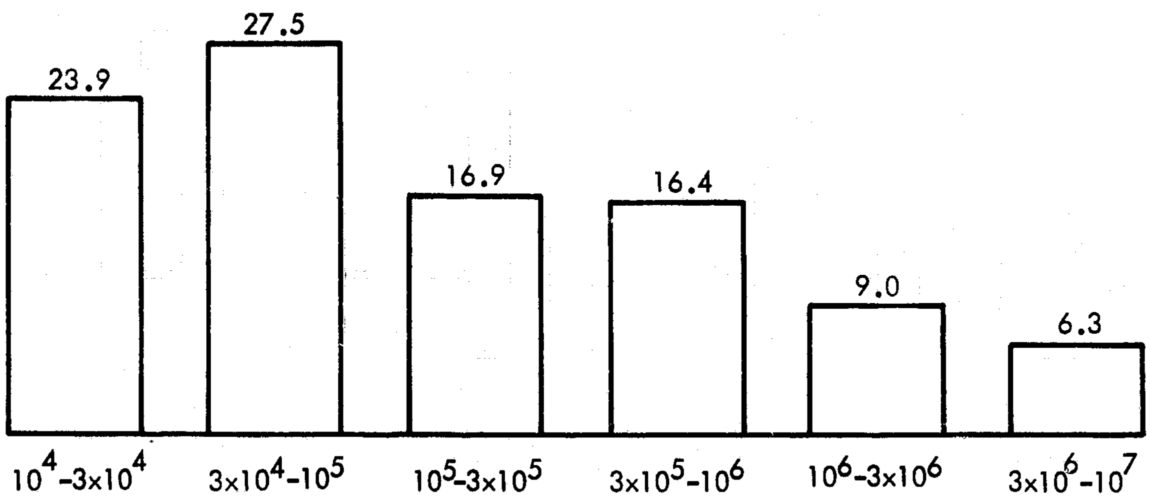

FIGURE 2.5-8. PERCENT OF RESIDENTIAL TRAFFIC BY CITY SIZE (FOR CITIES WITH POPULATIONS ABOVE 10,000)

The business traffic distribution of Figure 2.5-7 also serves as a descriptor for the WATS, Private Line, and MTS Business components of Voice traffic. Thus Figure 2.5-7 may be used to represent the distribution with respect to city size of most of the service categories defined in this report. The sole major exception (other than Network TV and CATV as mentioned above) is the category of Voice traffic referred to as MTS Residential. This component of Voice traffic follows the distribution of residential traffic vs city size presented in Figure 2.5-8.

2.5.3 GEOGRAPHICAL DISTRIBUTION OF TRAFFIC DENSITY

This section estimates the density of communications traffic per square mile throughout he United States. The long distance communications demand for the United States as developed in Sections 2.1 through 2.4 was organized for this purpose into three groupings as follows:

Residential	- MTS Residential only from Table 2.4-2.
Network TV	- From Table 2.4-5
Business	- All other categories in Tables 2.4-2, 2.4-5, and 2.4-8.

To estimate the traffic per unit area over the United States, the Residential and Business traffic as defined above was distributed over the United States in proportion to the number of residential and business telephones existing in each state as obtained from Reference 2.1-9. Network TV traffic was assigned proportionately to the three metropolitan areas in which this traffic originates, i.e., New York, Los Angeles, and Washington, D.C. and is included in the associated states.

The total traffic for each geographic region was then divided by the land area of that region to obtain traffic density per unit area. Results are displayed in Figures 2.5-9, 2.5-10, and 2.5-11, for the years 1980, 1990 and 2000, respectively. The density ranges indicated on the maps are decade ranges defined as follows:

Very Low	- .01 to 0.1 terabits per year per square mi.
Low	- 0.1 to 1.0
Medium	- 1.0 to 10
High	- 10 to 100

The results confirm expected patterns, with the higher traffic densities primarily concentrating in the Northeast. In 1980, only three percent of the total U.S. area generates more than one terabit per square mile annually. By 1990, eighteen percent of the area generates more than one terabit per square mile annually, and by the year 2000 this level of traffic originates from almost a third of the area of the U.S.

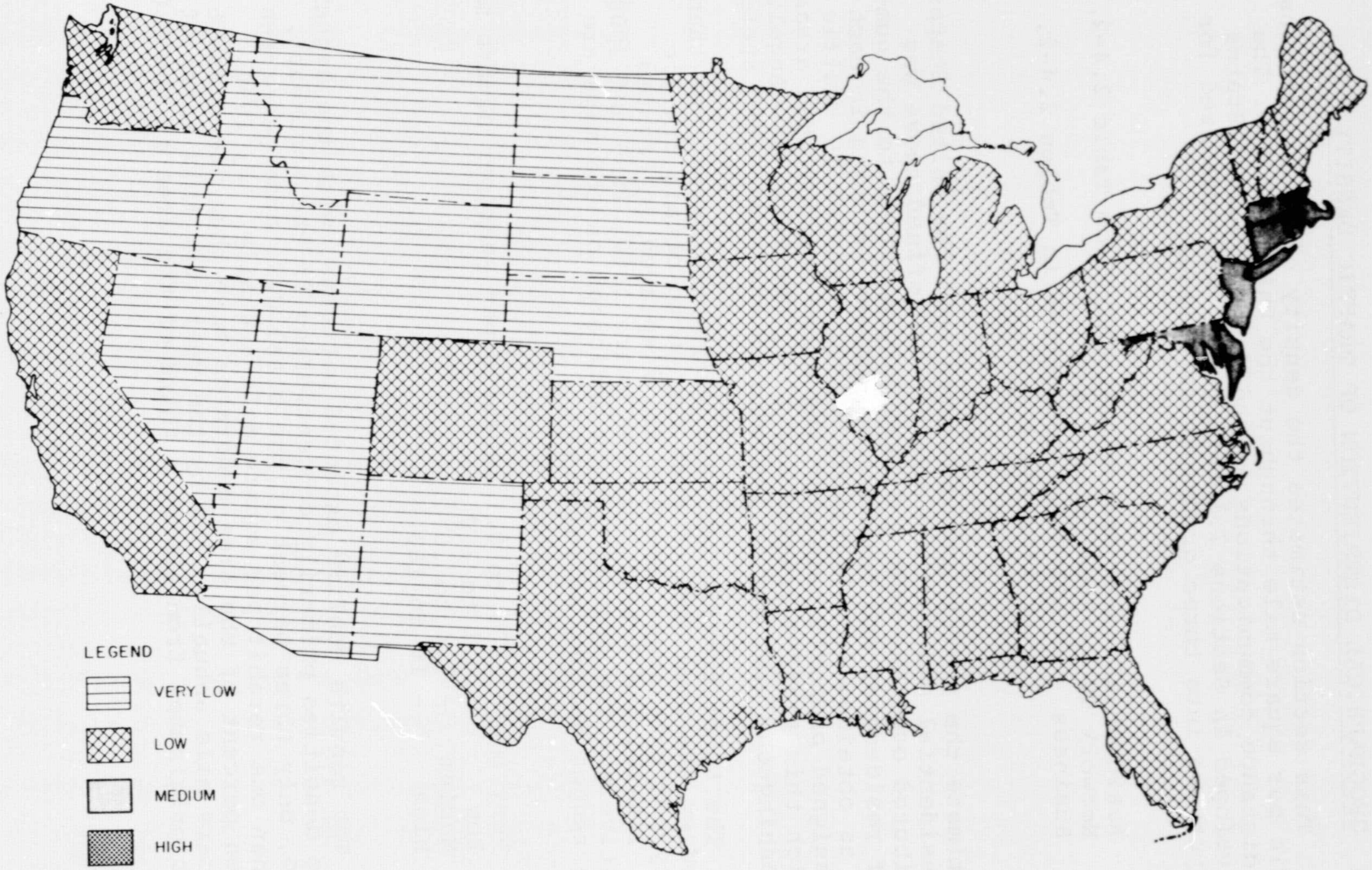

FIGURE 2.5-9. TRAFFIC DENSITY - 1980

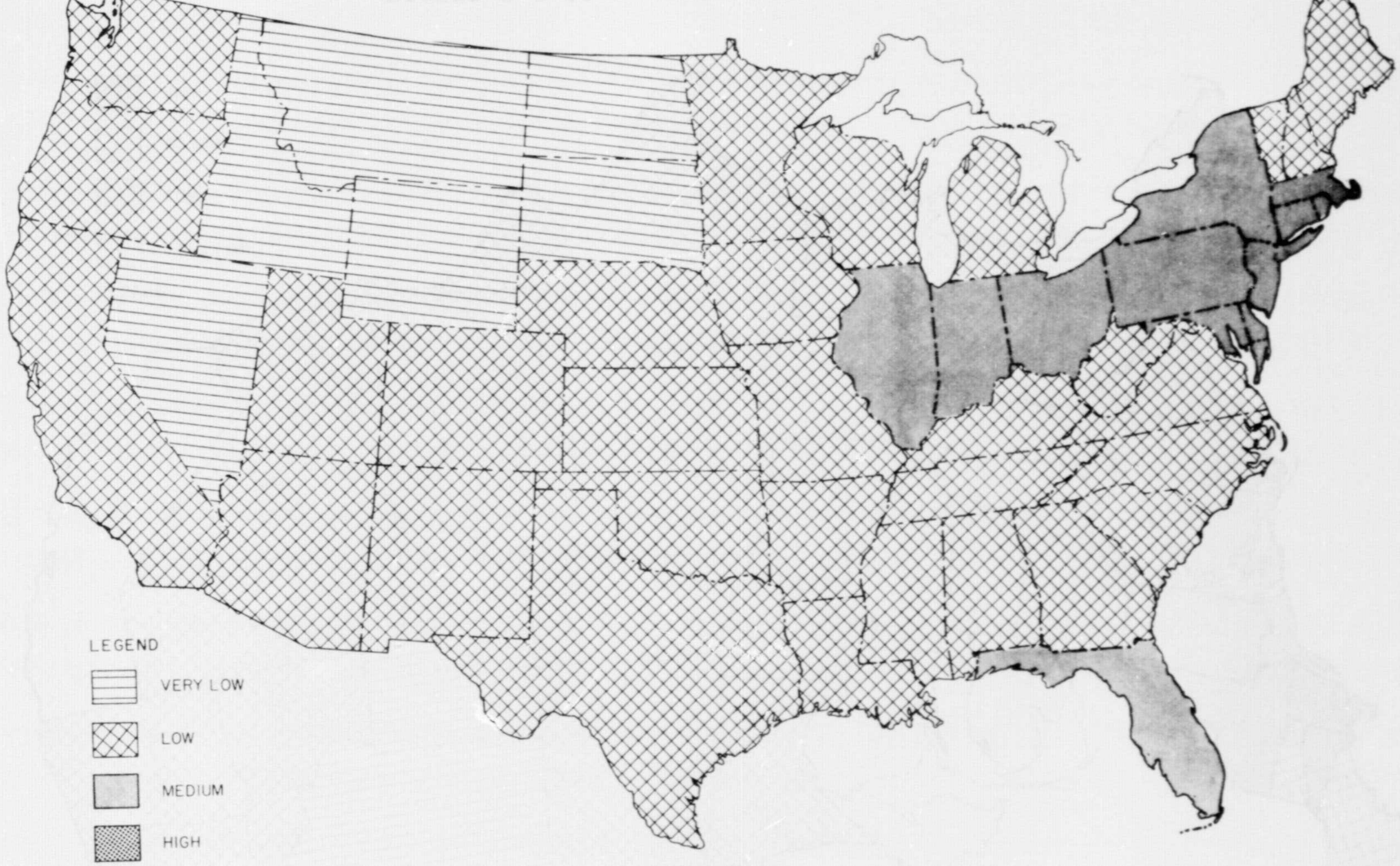

FIGURE 2.5-10. TRAFFIC DENSITY - 1990

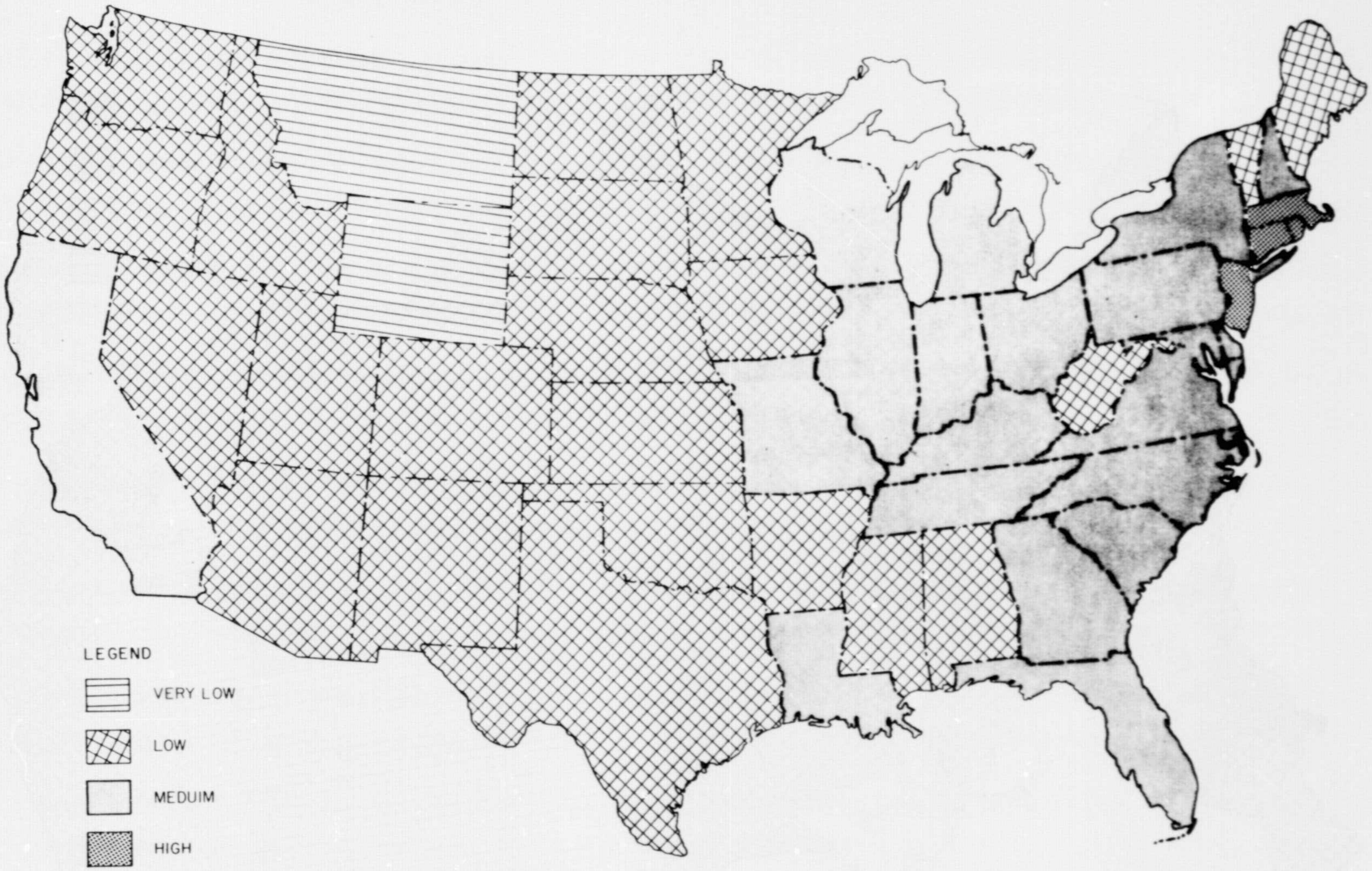

FIGURE 2.5-11. TRAFFIC DENSITY - 2000

2.6 SENSITIVITY OF SERVICE DEMAND TO PRICE VARIATIONS

This section discusses the effect of price changes on the demand for communications service. In economic theory the sensitivity of demand to price change is referred to as demand elasticity, and is defined as the percent change in demand divided by the percent change in price. Demand elasticity is generally expressed as a negative number, reflecting the fact that as prices rise demand decreases.

Two extremes of elasticity are represented by:

(a) Perfectly inelastic demand in which cost changes have no effect on demand.

(b) Perfectly elastic demand in which changes in cost result in extreme changes in demand.

In most cases of practical interest, elasticity lies between these extremes, but may be characterized in individual cases as being relatively elastic or relatively inelastic.

In the present discussion of communications demand, both elastic and inelastic behavior is of interest. When communications as a whole is under consideration, demand tends to be inelastic since the alternatives available to users faced with a price increase are few and require major changes in accustomed procedures. When, however, a limited isolated segment of communications (e.g., satellite transmission) is considered, within the context of the overall communications plant, a price differential for that isolated segment may be expected to cause significant (highly elastic) changes in demand.

The following discussion considers the demand elasticity for communications services for (a) the inelastic demand situation applicable when considering the cost of using the overall communications plant, and (b) the elastic demand situation pertaining to user reactions to costs of a specific segment of the overall communications system.

2.6.1 ELASTICITY OF THE OVERALL COMMUNICATIONS PLANT

Several recent studies have addressed the elasticity of telephone service and offer estimates for elasticity values. All of these studies indicate that improved data bases would be helpful in enhancing confidence in the estimates. A 1977 study by J. H. Alleman (Ref. 2.6-1) cites a number of elasticity estimates varying to as far negative as -0.4, but the focus of this study is on local telephone service, and it is therefore of only marginal interest to this study.

A second study presented in the Probe Telecommunications Journal (Ref. 2.6-2) analyzes a 1976 New York Telephone Company submission which includes an application for a "restriction" allowance. Restriction is defined as "... a measure of the amount of revenue lost when a rate is increased, due to the tendency of potential users to restrict their usage in the face of higher charges." Restriction is therefore closely related to demand elasticity.

The New York Telephone Company submission uses past experience with price changes in various categories of service to arrive at elasticity coefficients as indicated in Table 2.6-1.

TABLE 2.6-1. SUMMARY OF DEMAND ELASTICITY COEFFICIENTS (Source New York Telephone)

Service Category	Elasticity Coefficient
Basic Monthly Charge	-.030
Terminal Equipment	-.162
Additional Message Units	-.294
Intrastate Toll	-.364
Total Intrastate (Weighted)	-.176

A third study by R. R. Auray, Director of Business Research, AT&T Long Lines Department (Ref. 2.6-3), explores customer response to changes in MTS rates. The analysis confirms the expectation that customer reactions to rate changes generally conform to those predicted by economic theory. Customers react by increasing or decreasing MTS usage in response to rate decreases or increases (Figure 2.6-1), and in some cases react by changing their calling patterns to adjust to

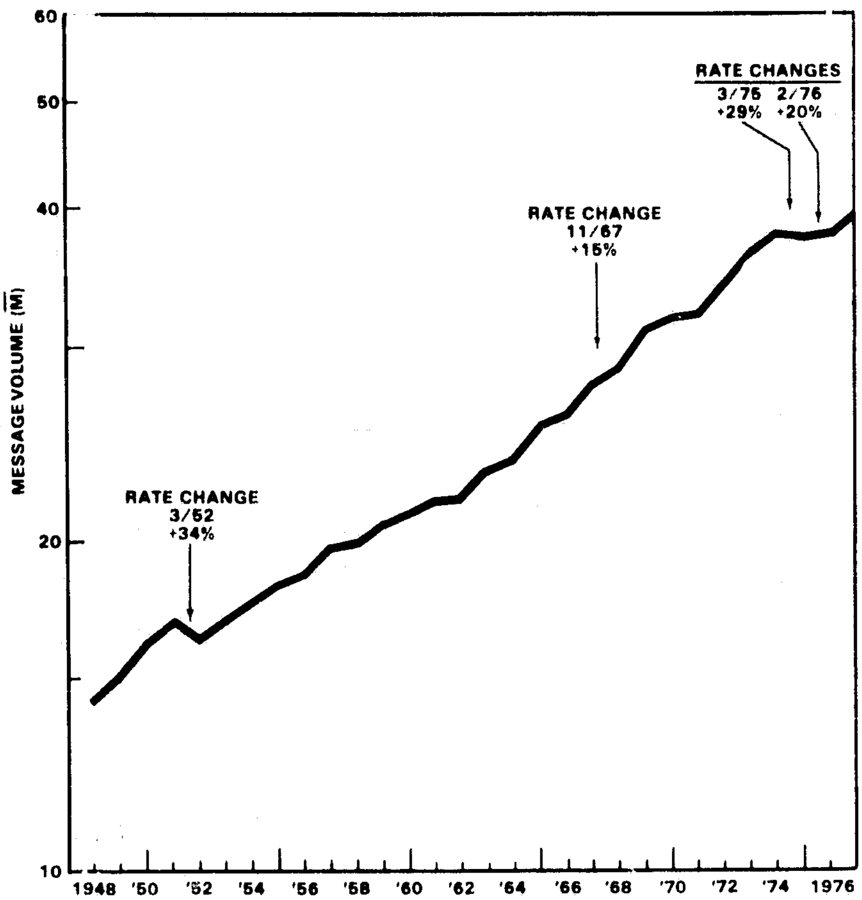

FIGURE 2.6-1. OCTOBER DOMESTIC INTERSTATE MESSAGE VOLUME ADJUSTED FOR EQUIVALENT BUSINESS DAYS, 1 - 24 MILES (Source Ref. 2.6-3)

changes in rate differentials between time periods (Figure 2.6-2). Additionally, the customer's reaction to MTS rate changes is not instantaneous; a period of time is required for full customer reaction to take effect. The reaction time for price elasticity, as seen in Figure 2.6-1, is in the range of two to eight months, while the reaction time for cross elastic effects, shown in Figure 2.6-2, may require one to two years.

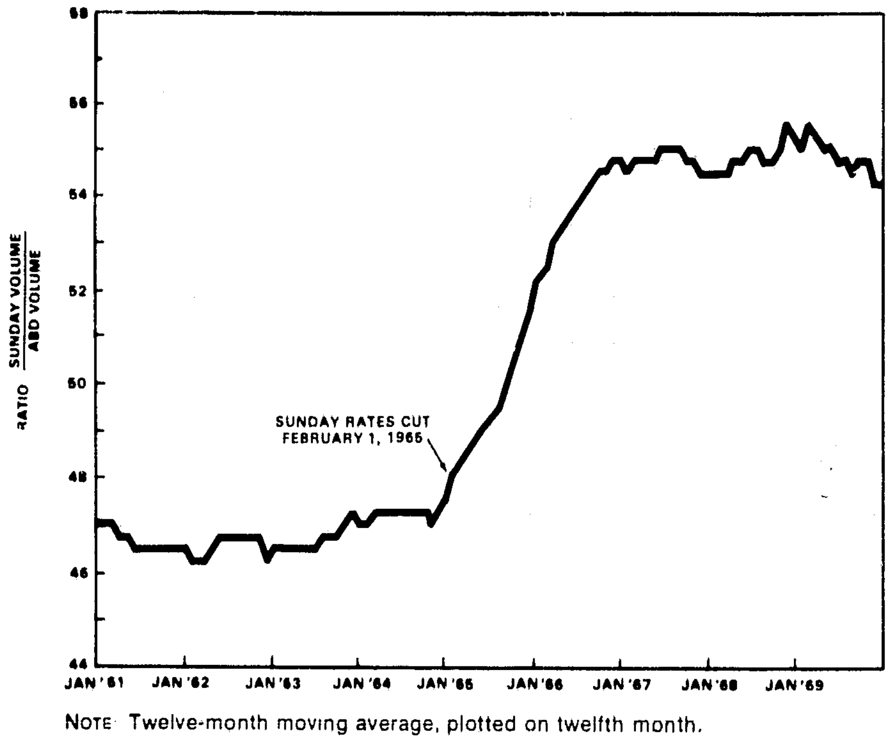

FIGURE 2.6-2. RATIO OF SUNDAY MESSAGE VOLUME TO AVERAGE BUSINESS DAY (ABD) MESSAGE VOLUME (Source Ref. 2.6-3)

Another conclusion to be drawn from the AT&T Long Lines study is that price elasticities differ by customer class, and both may increase with the length of haul. These results are shown in Table 2.6-2, with weighted averages developed according to the distance band and business/residential mixes developed in Section 2.1.1.

The overall average elasticity of -0.198 is not very far from the value of -0.176 resulting from the New York Telephone study summarized in Table 2.6-1.

TABLE 2.6-2. PRICE ELASTICITY OF MTS SERVICE DEMAND[1]

Mileage Band	Business	Residence
1-55	-.10	-.11
56-220	-.07	-.16
221-506	-.16	-.27
507-925	-.25	-.51
926-3000	-.10	-.39
Average (Weighted)[2]	-.129	-.273
Overall Average[3]	-.198	

(1) Data obtained from Ref. 2.6-3.

(2) Weighted with 1976 message volume distribution from Table 2.1-8.

(3) Weighted by 52%/48%, business/residential traffic mix.

2.6.2 ELASTICITY OF AN ISOLATED SEGMENT OF THE COMMUNICATIONS SYSTEM.

In the present study interest centers on the behavior of a more or less limited segment of communications (i.e., satellite communications, or, more restrictively, 30/20 GHz satellite communications) as well as on the elasticity of the overall communications plant. In the case of an isolated and limited segment of communications, users have a viable alternative and can avoid price differentials by switching to alternative communications modes. Demand elasticity in this case may therefore be expected to be more highly negative (more elastic) than is the case for the communications system as a whole.

The literature relating to this situation is less extensive than for the broader case previously discussed. However, a 1974 study conducted for ITT (Ref. 2.6-4) offers some insight into elasticity of a limited communications segment.

The study surveyed 831 business organizations with respect to their receptivity to an alternative communications supplier who might offer a new private line service. To be included in the randomly drawn sample, each company had to meet a $500,000 or more net worth criterion, and either have at least one interstate telecommunications line or use at least one hour per day of long distance communication between two specific telephone numbers.

Table 2.6-3 summarizes the responses of the users with respect to their willingness to change communication service suppliers on the basis of price or quality comparison with their present supplier.

As shown in Table 2.6-3 the capture ratios for a new supplier, given a 10 percent and 20 percent price discount, are .248 and .399 respectively. Subtracting the .085 users who apparently might change suppliers even without clearly defined price or quality differences, results in a net of .163, for a 10 percent price discount, and .313 for a 20 percent discount. These figures correspond to price elasticities of -1.63 and -1.57 for the 10 percent and 20 percent respective price discounts (fractional capture ratio divided by fractional price change.)

The results pertaining to a limited segment of communications presented above show, as might be expected, a much larger degree of elasticity than the results developed in Section 2.6.1 for the elasticity of the overall communications system.

TABLE 2.6-3. PERCENT OF USERS THAT WOULD CONVERT FROM EXISTING SUPPLIER

	Capture Ratio[1]
A. Rate Level Criteria[2]	
10% Lower than current supplier	.248
20% Lower than current supplier	.399
B. Quality Level Criteria	
Same as current supplier	.085
Somewhat better than current supplier	.150
Significantly better than current supplier	.257

(1) Total number of lines to be converted ÷ Total number of potential lines that could be converted.

(2) Assumes quality is the same as that of current supplier.

Table 2.6-3 also permits a comparison between improvement in quality and reduction in costs as they affect demand. While quantitative comparisons cannot be made, it appears that for the respondents to this survey a 10 percent cost reduction would be more important than service quality described as "somewhat better than current supplier," and would come close to equalling service quality described as "significantly better."

2.6.3 ELASTICITY OF SERVICE DEMAND

The results cited in the previous sections indicate that the demand for overall communications is relatively inelastic and has a value of about -0.2. However, if an isolated communication segment such as satellite communications is considered relative to the total communications plant, demand is much more elastic and has a value of about -1.6.

The information developed above is based on studies of telephone communication and as such applies most directly to the Voice service and to much of the Data service. The relatively elastic or inelastic values may be selected depending on whether the viewpoint of the investigation is that appropriate to the overall communications plant or to a small segment thereof. The values stated are average values and should be modified upward or downward to apply to particular situations and to particular components of service. Some of the more important service components are briefly discussed below.

In the Voice service category, business traffic tends to be less elastic than residential (see Table 2.6-2). MTS Business, WATS, and Private Line traffic will therefore generally show less elasticity than MTS Residential traffic.

Most Data traffic is business oriented and (with the following exceptions) should also be somewhat less elastic than the average values would indicate. Notable exceptions, however, exist in the case of Electronic Mail, which is in competition with the postal system and cannot be expected to sustain prices inordinately higher than the cost of first class mail. Similarly in the Terminal to CPU area, high communication costs will, in the long range, tend to promote the use of intelligent terminals and local processors to avoid excessive costs for remote access.

Video traffic will vary widely in elasticity, depending on which component of Video is in question. Network TV and CATV will be relatively inelastic. Communications costs for these are of lesser significance to the users than tested and familiar services. However, users of Videoconferencing are strongly concerned with costs and may be expected to regard Videoconferencing as desirable only so far as it offers an economic alternative to travel. Similarly, users of Educational Video may be expected to regard this service as a cost saving approach to distributing education and will use alternative methods if economic justification is not clear.

3.0 USER MARKET IDENTIFICATION

This section identifies the total long haul traffic in terms of user categories and geographical distribution. Four user groups are included and are defined as follows:

(1) Private individuals. This category includes all traffic generated by individual households.

(2) Business. This category includes all traffic generated by commercial businesses excluding institutions included in Item 4.

(3) Government. This category includes all traffic generated by the various government subdivisions and agencies.

(4) Institutions. The Institution category primarily consists of organizations which provide health care (e.g., hospitals), educational services (e.g., universities), and social welfare services (e.g., charities and religious organizations).

The geographical groupings selected are based on the Standard Industrial Classifications Manual and are as follows:

New England: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut.

Middle Atlantic: New York, New Jersey, Pennsylvania.

East North Central: Ohio, Indiana, Illinois, Michigan, Wisconsin.

West North Central: Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, Kansas.

South Atlantic: Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida.

East South Central: Arkansas, Louisiana, Oklahoma, Texas.

Mountain: Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada.

Pacific: Washington, Oregon, California (excluding Alaska and Hawaii).

3.1 SERVICE TYPES

The traffic demand projected for each service type is subdivided into the four user categories defined above. The basis for the segmentation into each user category is discussed below.

3.1.1 VOICE SERVICES

Total traffic for the voice services is given in Section 2.1. The "private" category as used in Section 3 is equivalent to the residential category used in the previous section. The non-residential traffic of Section 2, however, is further subdivided among Government, Institutional and Business users. The division is accomplished by starting with the total voice traffic in terabits from Table 2.4-2 and allocating it to Government, Institutions and Business in proportion to the number of traffic "generators" in each user category. The procedure followed assumed that the amount of traffic assignable to each category is proportional to the number of employees in that category.

Labor Department data (Ref. 3.1-1) provides accurate information on the number of employees in each sector of the economy. The latest data available, however, is for the base year of 1977. This data was projected to 1980, 1990, and 2000 in proportion to the anticipated increase in the population for these years.

The above mentioned statistics are segregated into "business" and "institutions" by allocating hospitals, elementary and secondary schools, colleges and universities, and welfare and religious agencies to the institution category. The Bureau of Labor Statistics also provides total government employment, including a count of federal, state, and local government employees, allowing the direct projection of the government user category. The growth rate of voice traffic applicable to 1980, 1990, and 2000 is obtained from the growth rate for residential and non-residential traffic presented in Section 2.

Table 3.1-1 shows the distribution of total voice traffic for the benchmark years by the four user categories. Table 3.1-2 gives the traffic distribution by user category in terms of a percentage of the total traffic for that service type. The results indicate that although voice traffic is projected to increase by five times from 1980 to 2000, the proportion attributable to each of the four user categories stays nearly constant.

The business sector accounts for nearly 60 percent of the satellite suitable voice traffic with the other three user categories dividing the remainder almost equally. Section 2 shows that residential voice traffic is a large component when considered on a total traffic basis, but only amounts to 13 to 14 percent of total long distance traffic when the 200 mile criteria is used to determine satellite suitable traffic.

TABLE 3.1-1. DISTRIBUTION OF TRAFFIC BY USER CATEGORY (in thousands of terabits per year)

	Private	Business	Govt.	Inst.	Total (1)
Voice					
1980	81	322	90	66	559
1990	196	812	224	168	1400
2000	376	1676	491	347	2890
Video					
1980	-	61	-	22	83
1990	-	120	5	46	171
2000	4	266	14	134	418
Data					
1980	-	75	21	16	112
1990	3	188	53	36	280
2000	4	293	83	57	437
Total					
1980	81	458	111	104	754
1990	199	1120	282	250	1851
2000	384	2235	588	538	3745

(1) Traffic totals obtained from Tables 2.4-2, 2.4-5, and 2.4-8.

TABLE 3.1-2. DISTRIBUTION OF TRAFFIC BY USER CATEGORY (in percent by service type)

	Private	Business	Govt.	Inst.	Total
Voice					
1980	14	58	16	12	100
1990	14	58	16	12	100
2000	13	58	17	12	100
Video					
1980	-	73	-	27	100
1990	-	70	3	27	100
2000	1	64	3	32	100
Data					
1980	-	67	19	14	100
1990	1	67	19	13	100
2000	1	67	19	13	100

3.1.2 VIDEO SERVICES

Section 2 of this report divides video services into five components. The derivation of video traffic per user category in this section is based on a percentage allocation of private, business, government, and institution traffic for each service component. The values shown in Tables 3.1-1 and 3.1-2 in the rows corresponding to video are obtained by calculating a weighted average as a function of the total traffic in each service component. The percentage allocation is as follows:

(a) Network TV - Business 100 percent

(b) CATV - Business 100 percent

(c) Videoconferencing - Business 85 percent, Institutions 10 percent, Government 5 percent.

(d) Education - Institutions 100 percent

(e) Health and Public Affairs - Institutions 60 percent, Government 40 percent.

The traffic distribution shows that the generation of video traffic by private individuals (i.e., households) is projected to be negligible through the complete time frame applicable to this study. Nearly all the video traffic is the result of businesses and institutions. This results from the increasing impact of videoconferencing as a substitute for business visits and from the projected use of "television-lectures" at educational institutions, particularly universities, as well as the increased use of telediagnosis by medical institutions.

The results given in Table 2.4-5 provide the growth rate of video traffic by service components for the years 1980, 1990, and 2000. The percentage allocation of each service component given above was uniformly applied to each year's traffic totals to derive the results shown in Tables 3.1-1 and 3.1-2. It should be noted that the traffic given in Table 2.4-5 includes the application of the compression factors shown in Table 2.4-4, which results in a decrease in the share projected for business traffic. This is caused by the growing dominance of videoconferencing for business applications and the relatively high compression ratio (7:1) assigned to this application.

3.1.3 DATA SERVICES

Private user traffic for data service is negligible in 1980 and is allocated only one percent in 1990 and 2000. Nearly all the traffic, therefore, is divided between the business, government, and institution categories. The methodology used to derive the traffic distribution of the user categories for voice has also been used for data service. The results are presented in Tables 3.1-1 and 3.1-2.

Businesses are the predominant sources of data traffic and are projected to generate two-thirds of the total data traffic from 1980 to 2000. The remainder is divided between government and institutions with the government category accounting for almost 20 percent of the total and institutions 13 to 14 percent.

3.2 TRAFFIC DEMAND FOR TYPICAL USERS

Traffic demand by service type for typical users in each user category is estimated in this subsection. The approach taken is to select a major component of the user category and then to calculate the average size of an organization within that component. For example, a major component of the "Institutions" user category is schools of higher education, and the typical user is the average size university. This procedure permits an understanding of satellite suitable traffic demand from the more restricted viewpoint of the "typical user."

3.2.1 PRIVATE USERS

The typical private user is a residential household with one main telephone. Subsection 2.1 provides data giving the number of households and residential main telephones projected for 1980, 1990, and 2000. Since Table 3.1-1 segregates traffic by user category and year, the column labeled "Private" is used to calculate the voice, video and data services segment of a typical household's traffic. This is accomplished by dividing the traffic projected for each service type by the total number of residential main phones. The results obtained are presented in Table 3.2-1.

TABLE 3.2-1. TRAFFIC ESTIMATES FOR THE TYPICAL PRIVATE USER (in Megabits per Year)

SERVICE	1980	1990	2000
Voice	1034	1889	3064
Video	---	---	33
Data	---	29	33

Observation of the table indicates that voice traffic will continue to be the dominant source of traffic for the typical private user even in the year 2000. The specialized applications for video and data usage discussed in Section 2 are projected to contribute only about one percent each to the total in that year.

3.2.2 BUSINESS USERS

The typical business user was selected as the average for Fortune 500 companies. Although these companies are the largest, this component was chosen since they are the most likely to use newly emerging technologies in the voice, video, and data service categories described in Section 2. They are the prime candidates for videoconferencing and will certainly be among the first to install such facilities. Also, they will be in the lead in using the wide variety of services included in the data category. The Fortune 500 companies account for about two-thirds of the industrial production in the United States.

The methodology used for determining the traffic demand of the average Fortune 500 company is similar to that described above. The average number of employees in 1977 for this segment of businesses is 10,600 as calculated from Fortune data. The number was increased for 1980, 1990 and 2000 in proportion to the projected increase in the population. The share of the total business traffic given in Table 3.1-1 which can be allocated to this "typical" business user was then calculated by determining the ratio of the number of employees in the average Fortune 500 company to the total number of business employees projected for each subject year. This ratio was then applied to the traffic figures given in Table 3.1-1 for business. These calculations resulted in the data presented in Table 3.2-2.

TABLE 3.2-2. TRAFFIC ESTIMATES FOR THE TYPICAL BUSINESS USER (in Terabits per Year)

SERVICE	1980	1990	2000
Voice	62	157	324
Video	12	23	51
Data	14	36	57

The table shows that voice traffic will continue to dominate the business user category from 1980 to 2000. Although there will be substantial increases in the video and data service categories, the resultant traffic shows a much more modest growth due to the use of video compression techniques in the first case, and the use of more efficient transmission modes (i.e., packet switching), in the second.

3.2.3 GOVERNMENT USERS

State government was chosen to represent the typical user of the government user category. A state government is likely to use the variety of services included in the voice, video and data classifications.

The number of state employees in each state was obtained from the U.S. Bureau of the Census, Public Employment Series (Ref. 3.2-1). The latest available data gives state employment for the year 1977. The number of employees was projected to 1980, 1990, and 2000 in proportion to the general increase in the population. The "typical state" was defined as the average of all fifty states and, therefore, the total number of state employees was divided by fifty to obtain the number of employees in the typical state for each benchmark year.

Table 3.1-1 gives the total traffic for the government user category in 1980, 1990, and 2000. Dividing this total by the number of all government employees and then multiplying this result by the number of employees in the "typical state" gives the amount of traffic for each service type in the typical state. The results of the calculations are shown in Table 3.2-3.

TABLE 3.2-3. TRAFFIC ESTIMATES FOR THE TYPICAL GOVERNMENT USER (in Terabits per Year)

SERVICE	1980	1990	2000
Voice	407	1016	2212
Video	---	23	63
Data	95	240	374

The table indicates that voice is the largest traffic component for the typical government user. Data traffic provides a significant share of the total, accounting for nearly twenty percent of the total in 1980 and 1990, and fifteen percent in 2000. Video traffic represents a very small share of the total, having no more than a two percent share in 1990 and 2000. This is due in part to the video compression ratios projected in Table 2.4-4.

3.2.4 INSTITUTIONAL USERS

Schools of higher education were selected as the "typical user" representing the institutions category. In particular, colleges and universities can be expected to be in the forefront of institutions making use of video (for remote lecturing), and data transmission (for computer usage).

An average size university was used to calculate the traffic generated by this "typical user". The method used for this category was the same as used for the previous two user categories, that is, relating traffic demand to the number of employees. The number of employees at an average size university was determined by dividing the total number of employees at colleges and universities, as given in Ref. 3.1-1, by the number of institutions of higher education compiled by the United States National Center for Education Statistics (Ref. 3.2-2).

The institutions column of Table 3.1-1 gives the traffic for each of the three benchmark years by service type. Dividing these numbers by the total number of institutional employees and multiplying the result by the average number of employees at the typical institution provides the share of the traffic for each service type attributable to the typical institution. The growth of the number of employees per institution for 1980, 1990 and 2000 was made proportional to the population growth. The results obtained are shown in Table 3.2-4.

TABLE 3.2-4. TRAFFIC ESTIMATES FOR THE TYPICAL INSTITUTIONAL USER (in Terabits per Year)

SERVICE	1980	1990	2000
Voice	4	10.3	21.3
Video	1.3	2.8	8.2
Data	1.0	2.2	3.5

Observation of the table indicates that video and data have a relatively higher importance compared to the other "typical users" discussed previously. The combined total of the video and data services amounts to approximately fifty percent of the voice traffic. An important cause of this result is the use of television lecturing at universities.

3.3 DEMOGRAPHICS OF USER CATEGORIES

This subsection provides a series of maps and tables which illustrate the distribution of traffic in each user category on a regional basis. The nine regions shown on the maps conform to the Standard Industrial Classifications Manual and are explained in the introductory paragraph of this section.

3.3.1 VOICE SERVICES

Figures 3.3-1, 3.3-2, and 3.3-3 show the distribution of voice traffic by user category in the nine regions of the continental United States for the years 1980, 1990 and 2000, respectively, as a percentage of the total traffic for that service type. The accompanying Table, 3.3-1, gives the amount of traffic in thousands of terabits corresponding to the percentage of the total projected for that region.

The voice traffic estimated for each region is based on the number of residential and business main telephones in that region and the average traffic, translated to its digital equivalent, generated by residential and business main telephones. The data for the number of residential and business telephones is obtained from the latest edition of the Statistics of Communication Common Carriers prepared by the Federal Communications Commission (Reference 3.3-1).

As previously explained in Subsection 3.1, telephone company "business" traffic must be allocated to the three user categories of business, government, and institutions. This was accomplished by determining the distribution of business, government, and institutional employees in each of the nine standard industrial areas from data compiled by the U.S. Bureau of Labor Statistics (Reference 3.3-2). The distribution calculated in this manner was used with the statistics giving total traffic in the private, business, government, and institution categories from Table 3.1-1 in order to obtain voice traffic by user category in each of the nine standard regions.

In order to project the statistics for regional traffic to the years 1980, 1990 and 2000, it was necessary to determine the relative growth expected for each region from the U.S. Bureau of the Census Current Population Reports (Reference 3.3-3). The Census Bureau's Series II-A projections were used for the subject years since they take into consideration anticipated migration problems between regions.

The results indicate that three regions (Middle Atlantic, East North Central, and South Atlantic) contribute a bit more than half of the total voice traffic from 1980 to 2000. There

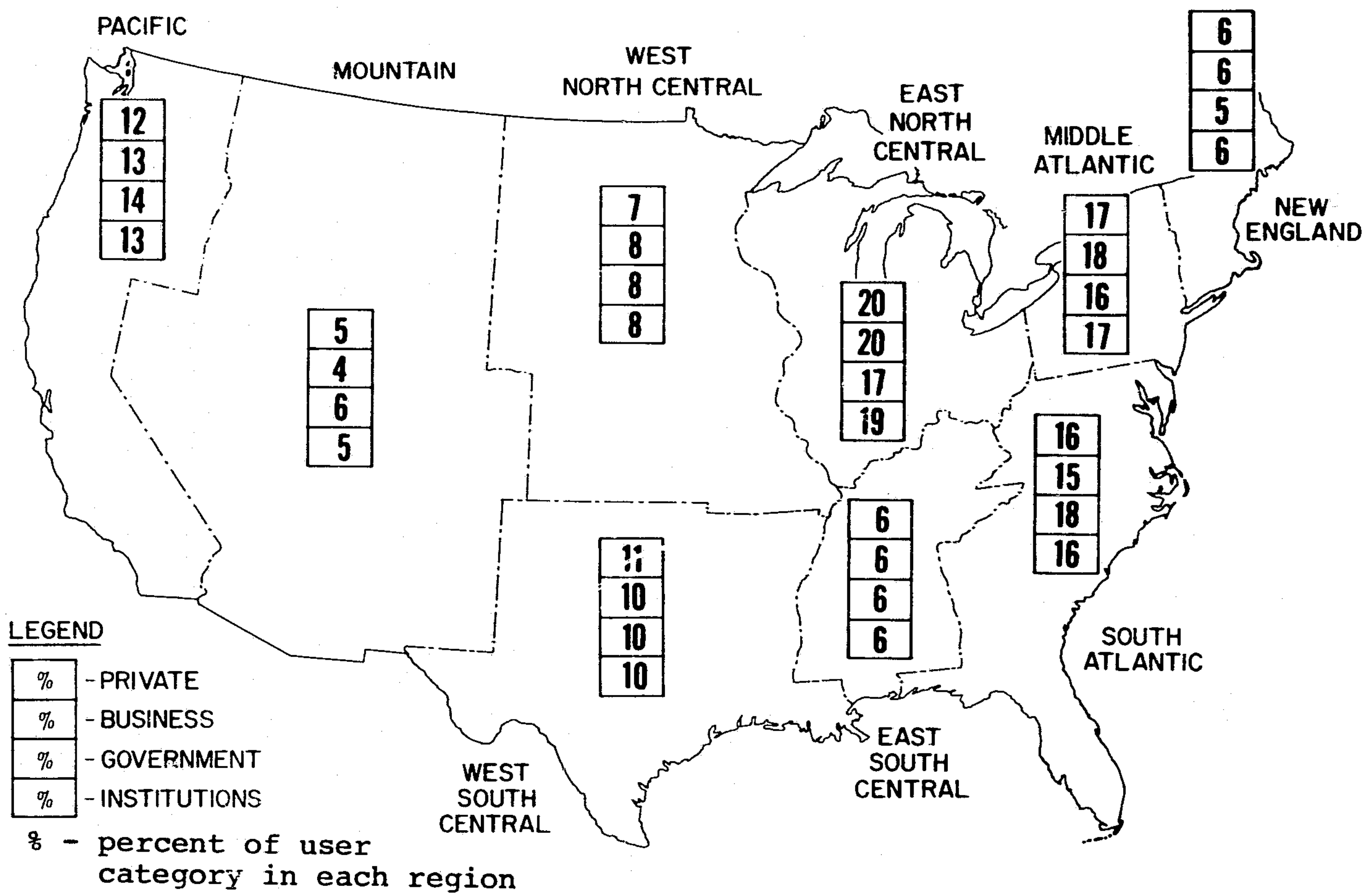

FIGURE 3.3-1. REGIONAL DISTRIBUTION OF VOICE TRAFFIC FOR 1980 BY USER CATEGORY

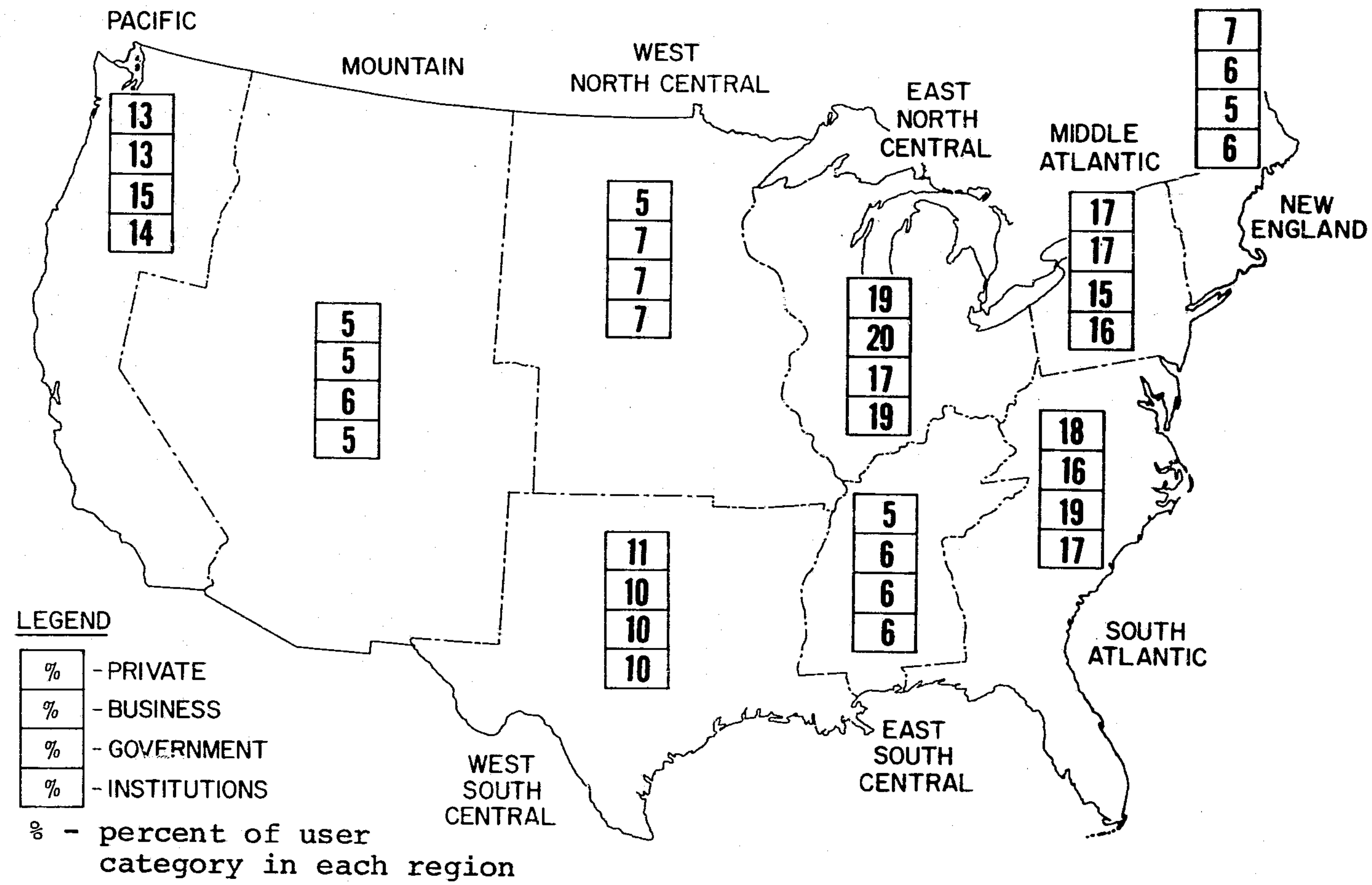

FIGURE 3.3-2. REGIONAL DISTRIBUTION OF VOICE TRAFFIC FOR 1990 BY USER CATEGORY

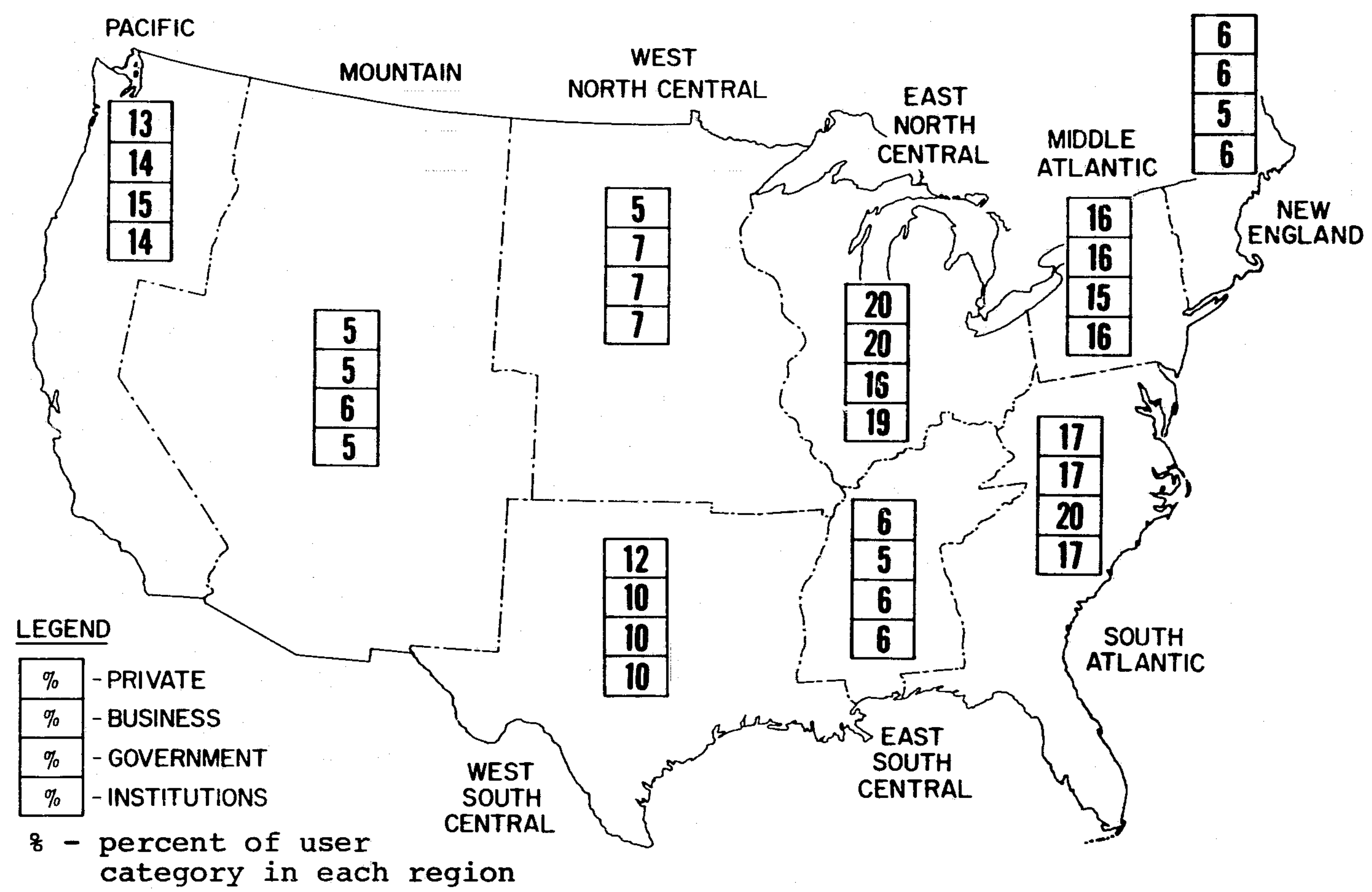

FIGURE 3.3-3. REGIONAL DISTRIBUTION OF VOICE TRAFFIC FOR 2000 BY USER CATEGORY

TABLE 3.3-1. VOICE TRAFFIC DISTRIBUTION BY REGION AND USER CATEGORY

Region	Private		Business		Government		Institutions		Total	
	%	Tr	%	Tr	%	Tr	%	Tr		

(a) Voice - 1980

New England	6	5	6	19	5	5	6	4	6	33
Middle Atlantic	17	14	18	58	16	15	17	11	18	98
East North Central	20	16	20	65	17	15	19	12	19	108
West North Central	7	5	8	26	8	7	8	5	8	43
South Atlantic	16	13	15	48	18	16	16	11	16	88
East South Central	6	5	6	19	6	5	6	4	6	33
West South Central	11	9	10	32	10	9	10	7	10	57
Mountain	5	4	4	13	6	5	5	3	4	25
Pacific	12	10	13	42	14	13	13	9	13	74
Total	14	81	58	322	16	90	12	66	100	559

(b) Voice - 1990

New England	7	14	6	49	5	11	6	10	6	84
Middle Atlantic	17	34	17	138	15	34	16	27	17	233
East North Central	19	37	20	162	17	38	19	32	19	269
West North Central	5	10	7	57	7	16	7	12	7	95
South Atlantic	18	36	16	130	19	43	17	29	17	238
East South Central	5	10	6	49	6	13	6	10	6	82
West South Central	11	22	10	81	10	22	10	17	10	142
Mountain	5	10	5	41	6	13	5	8	5	72
Pacific	13	23	13	105	15	34	14	23	13	185
Total	14	196	58	812	16	224	12	168	100	1400

(c) Voice - 2000

New England	6	22	6	100	5	25	6	21	6	168
Middle Atlantic	16	60	16	268	15	74	16	55	16	457
East North Central	20	75	20	335	16	79	19	66	19	555
West North Central	5	19	7	117	7	34	7	24	7	194
South Atlantic	17	64	17	285	20	98	17	59	18	506
East South Central	6	23	5	84	6	29	6	21	5	157
West South Central	12	45	10	168	10	49	10	35	10	297
Mountain	5	19	5	84	6	29	5	17	5	149
Pacific	13	49	14	235	15	74	14	49	14	407
Total	13	376	58	1676	17	491	12	347	100	2890

(Tr = Traffic in thousands of terabits per year)

is a projected shift of two percent from the Middle Atlantic to the South Atlantic region during this time period as a result of the general population migration from the Northeast to the Southeast. Voice, being a traditional and relatively stable service, shows progressive growth with no startling changes. In general, the regional traffic distribution conforms with the regional population percentage.

3.3.2 VIDEO SERVICES

Figures 3.3-4, 3.3-5, and 3.3-6 give the distribution of video traffic by user category for each of the nine standard regions. Table 3.3-2 gives the regional video traffic translated to its equivalent digital capacity by user category.

The regional video traffic by user category was derived for 1980 by a direct count of current video users and adding anticipated increases for the short term from current time to 1980. This procedure was only possible for 1980 since the number of video traffic generators in each category is relatively small. The 1990 and 2000 periods, however, required the use of an estimation procedure to develop the traffic anticipated for these years.

The estimating procedure for 1990 and 2000 starts with the video traffic projections given in Table 2.4-5 in terms of terabits. The regional allocation for the Network TV and CATV traffic shown for 1980 was used as the basis for the 1990 and 2000 estimates. The projection was performed by using the growth predicted for these two subcategories in Section 2 allocating the anticipated 1990 and 2000 traffic in the same ratio as determined for 1980.

A different technique was used for videoconferencing since the projections for this significant subcategory were based on an anticipated substitution for business travel. It was necessary, therefore, to determine the number of business employees in each of the nine standard industrial regions, and to project the numbers to 1990 and 2000 by the procedure explained in paragraph 3.1.2.

The Educati ˀ and Health and Public Affairs subcategories were handled in a similar manner. Both of these video service types are involved in providing support services to the general public and, therefore, the traffic demand developed by each is proportional to the populations they serve. The regional population statistics and projections were obtained from the data given in Reference 3.3-3. The traffic predicted for these two categories in Table 2.4-5, therefore, was allocated to each of the nine standard regions in the same ratio as their anticipated populations. The division of Education and Health and Public Affairs traffic into the four user categories followed the allocation formula given in Subsection 3.1.

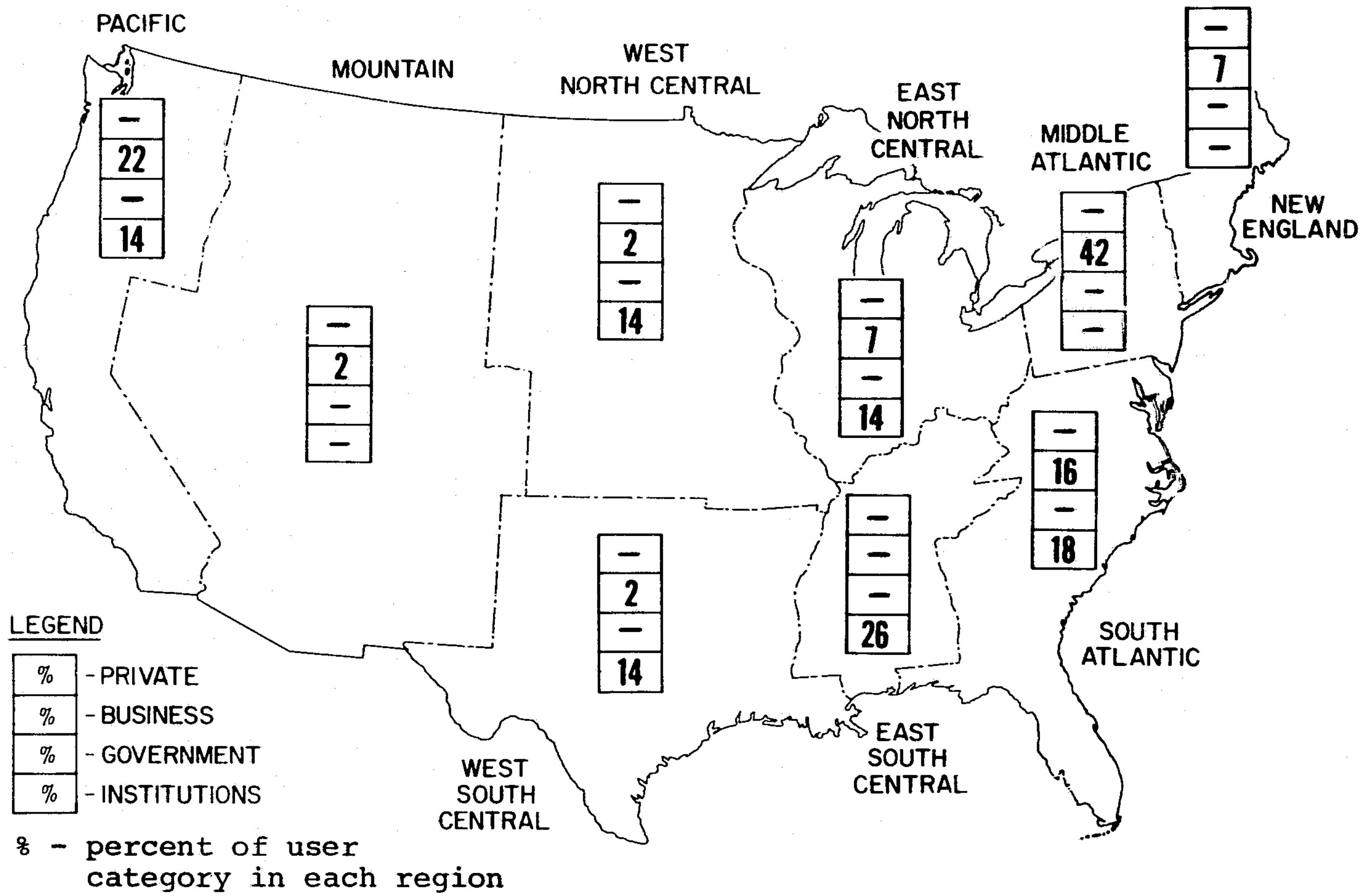

FIGURE 3.3-4. REGIONAL DISTRIBUTION OF VIDEO TRAFFIC FOR 1980 BY USER CATEGORY

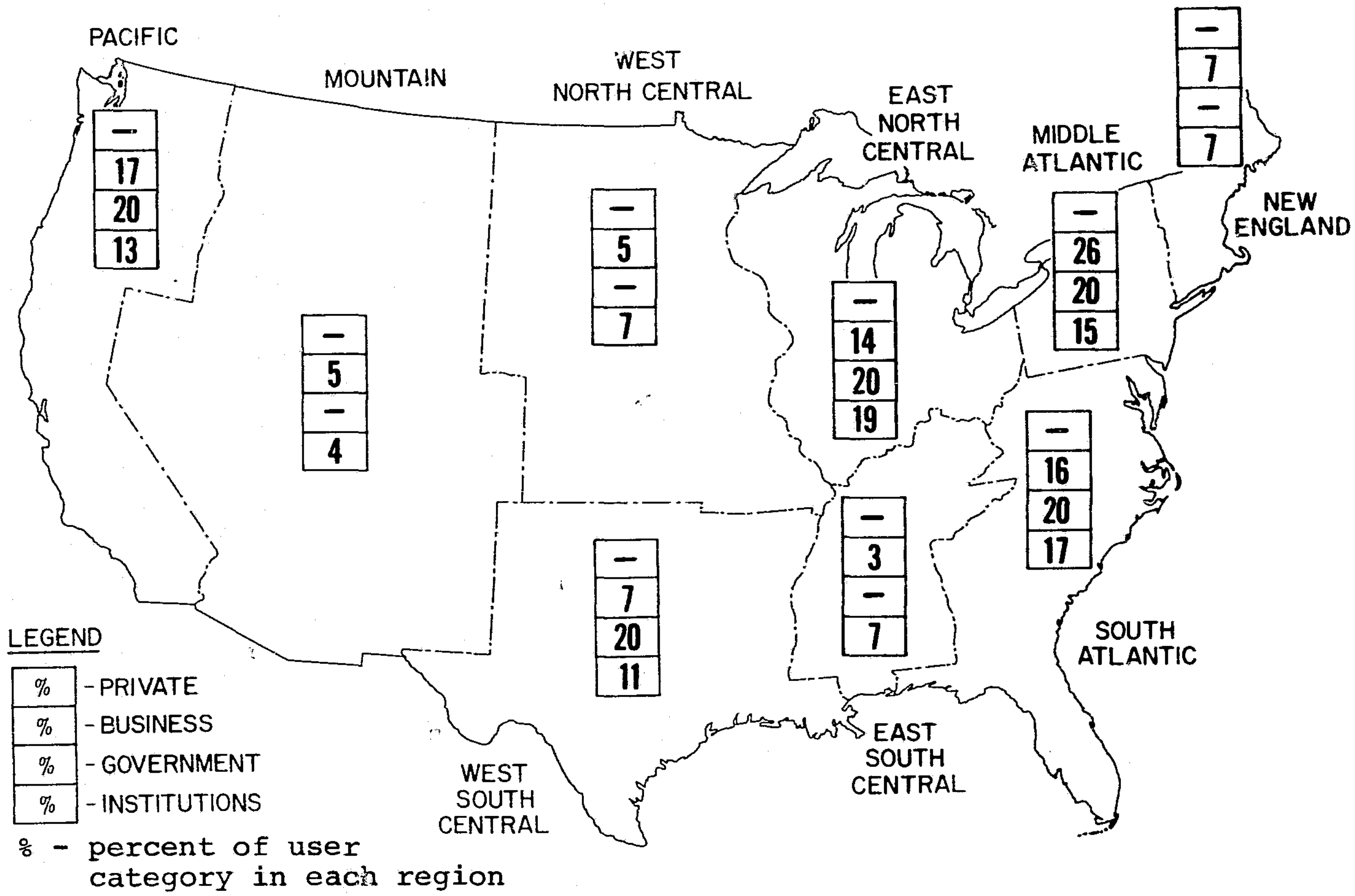

FIGURE 3.3-5. REGIONAL DISTRIBUTION OF VIDEO TRAFFIC FOR 1990 BY USER CATEGORY

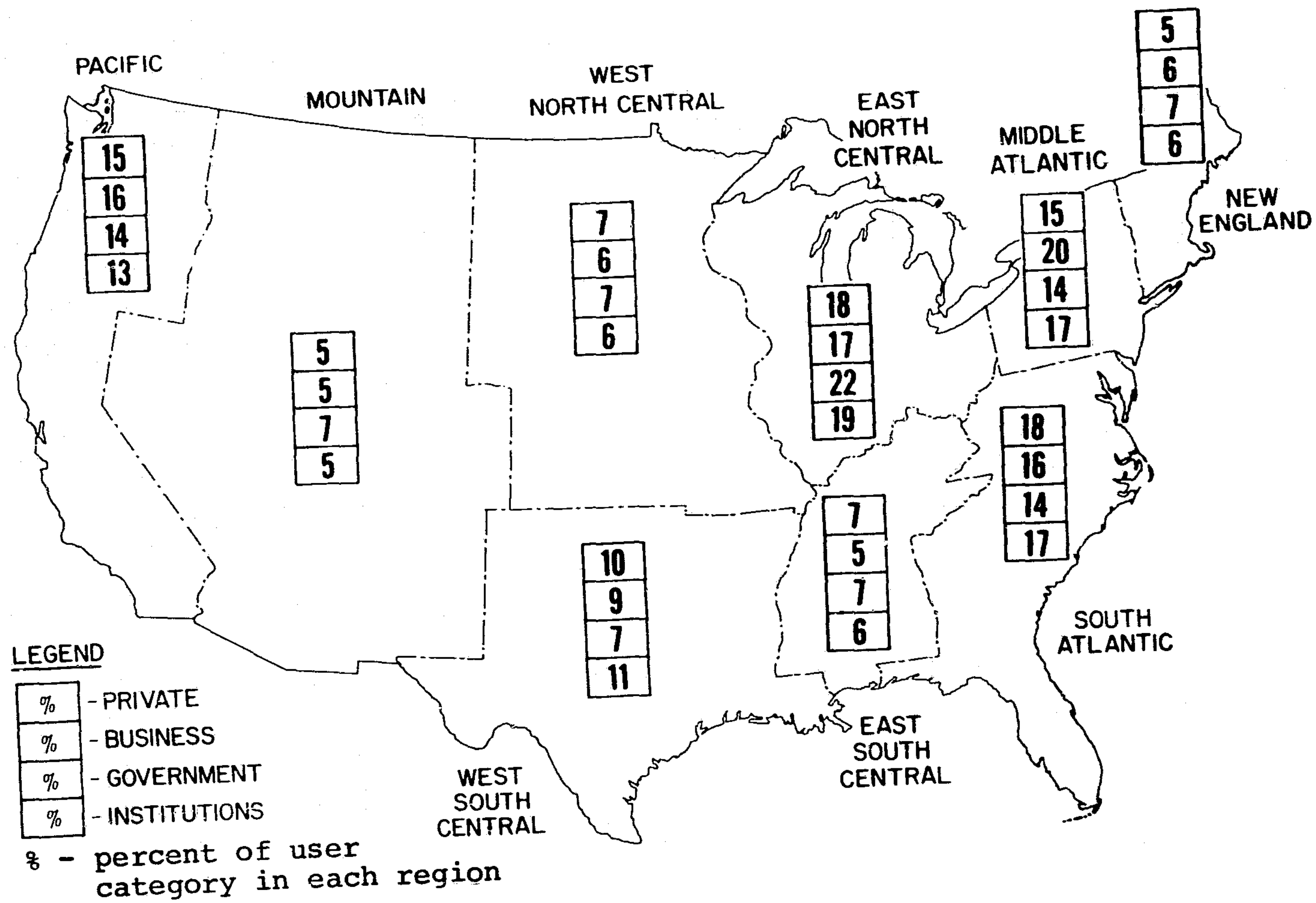

FIGURE 3.3-6. REGIONAL DISTRIBUTION OF VIDEO TRAFFIC FOR 2000 BY USER CATEGORY

TABLE 3.3-2. VIDEO TRAFFIC DISTRIBUTION BY REGION AND USER CATEGORY

Region	Private		Business		Government		Institutions		Total	
	%	Tr	%	Tr	%	Tr	%	Tr		

(a) Video - 1980

New England	-	-	7	4	-	-	-	-	5	4
Middle Atlantic	-	-	42	26	-	-	-	-	31	26
East North Central	-	-	7	4	-	-	14	3	8	7
West North Central	-	-	2	1	-	-	14	3	5	4
South Atlantic	-	-	16	10	-	-	18	4	17	14
East South Central	-	-	-	-	-	-	26	6	7	6
West South Central	-	-	2	1	-	-	14	3	5	4
Mountain	-	-	2	1	-	-	-	-	1	1
Pacific	-	-	22	14	-	-	14	3	21	17
Total	-	-	73	61	-	-	27	22	100	83

(b) Video - 1990

New England	-	-	7	8	-	-	7	3	7	11
Middle Atlantic	-	-	26	31	20	1	15	7	23	39
East North Central	-	-	14	17	20	1	19	9	16	27
West North Central	-	-	5	6	-	-	7	3	5	9
South Atlantic	-	-	16	19	20	1	17	8	16	28
East South Central	-	-	3	4	-	-	7	3	4	7
West South Central	-	-	7	8	20	1	11	5	8	14
Mountain	-	-	5	6	-	-	4	2	5	8
Pacific	-	-	17	21	20	1	13	6	16	28
Total			70	120	3	5	27	46	100	171

(c) Video - 2000

New England	5	.2	6	17	7	1	6	8	6	26
Middle Atlantic	15	.6	20	52	14	2	17	22	19	77
East North Central	18	.7	17	46	22	3	19	25	18	75
West North Central	7	.3	6	17	7	1	6	8	6	26
South Atlantic	18	.7	16	43	14	2	17	22	16	68
East South Central	7	.3	5	13	7	1	6	8	5	22
West South Central	10	.4	9	24	7	1	11	14	9	39
Mountain	5	.2	5	12	7	1	5	7	5	20
Pacific	15	.6	16	42	14	2	13	20	16	65
Total	1	4.0	64	266	3	14	32	134	100	418

(Tr = Traffic in thousands of terabits per year)

Private video traffic is projected to be negligible in the years of 1980 and 1990. In 2000, however, a small but countable component of approximately one percent is anticipated. Since the private category corresponds to households, the regional traffic division is directly proportional to the regional population.

Observation of the data on Figures 3.3-4, 3.3-5, and 3.3-6 and Table 3.3-2 indicates that video service is sensitive to region. In 1980, nearly seventy percent of all video traffic is contributed by three regions: Middle Atlantic, South Atlantic, and Pacific. This is primarily due to the current concentration of network television, CATV program generation, and educational program generation in these regions.

The regional distribution becomes progressively more dispersed in 1990 and 2000. This results from the growing importance of the Videoconferencing and Health and Public Affairs components. The data indicates that four regions, Middle Atlantic, East North Central, South Atlantic and Pacific, account for a bit more than seventy percent of the traffic in 1990 and a bit less than seventy percent in 2000.

3.3.3 DATA SERVICES

Figures 3.3-7, 3.3-8 and 3.3-9 present the geographical distribution of the Data Services traffic by user category for 1980, 1990 and 2000. Table 3.3-3 shows the projected data traffic demand allocated to each region. Tables 2.4-8 and 3.1-1 give the traffic totals for the Data Services segment for each of the benchmark years.

A methodology similar to that used for voice traffic was used for data traffic. The major difference is that the private component for data is insignificant, contributing only one percent in 1990 and 2000. Of the three other user categories, business, government, and institutions, business accounts for two-thirds of the total. As a result, the estimation procedure relates data traffic to the projection of the number of employees in each user category for each of the nine standard regions.

The methodology explained in paragraph 3.3.1 for allocating employees by user category to each region is identical to the procedure used here. The same statistical sources cited in paragraph 3.3.1 were used to allocate the data traffic to each standard region.

The results indicate that three regions account for slightly more than half the total data traffic in all three benchmark years. These regions, Middle Atlantic, East North Central, and South Atlantic, when combined with the Pacific and West South Central regions, include three-quarters of the total. This is the result of the population and business concentration in these areas.

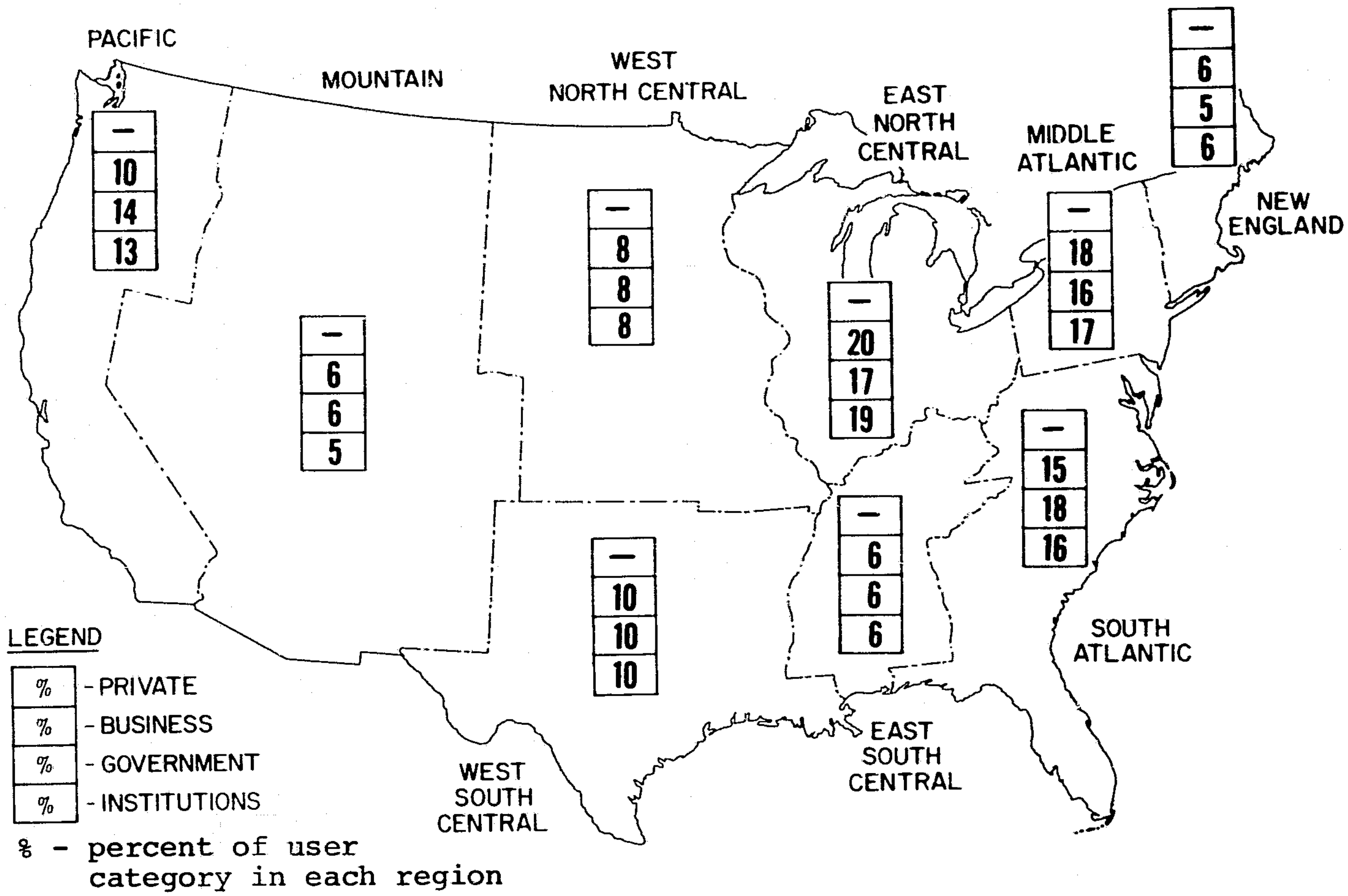

FIGURE 3.3-7. REGIONAL DISTRIBUTION OF DATA TRAFFIC FOR 1980 BY USER CATEGORY

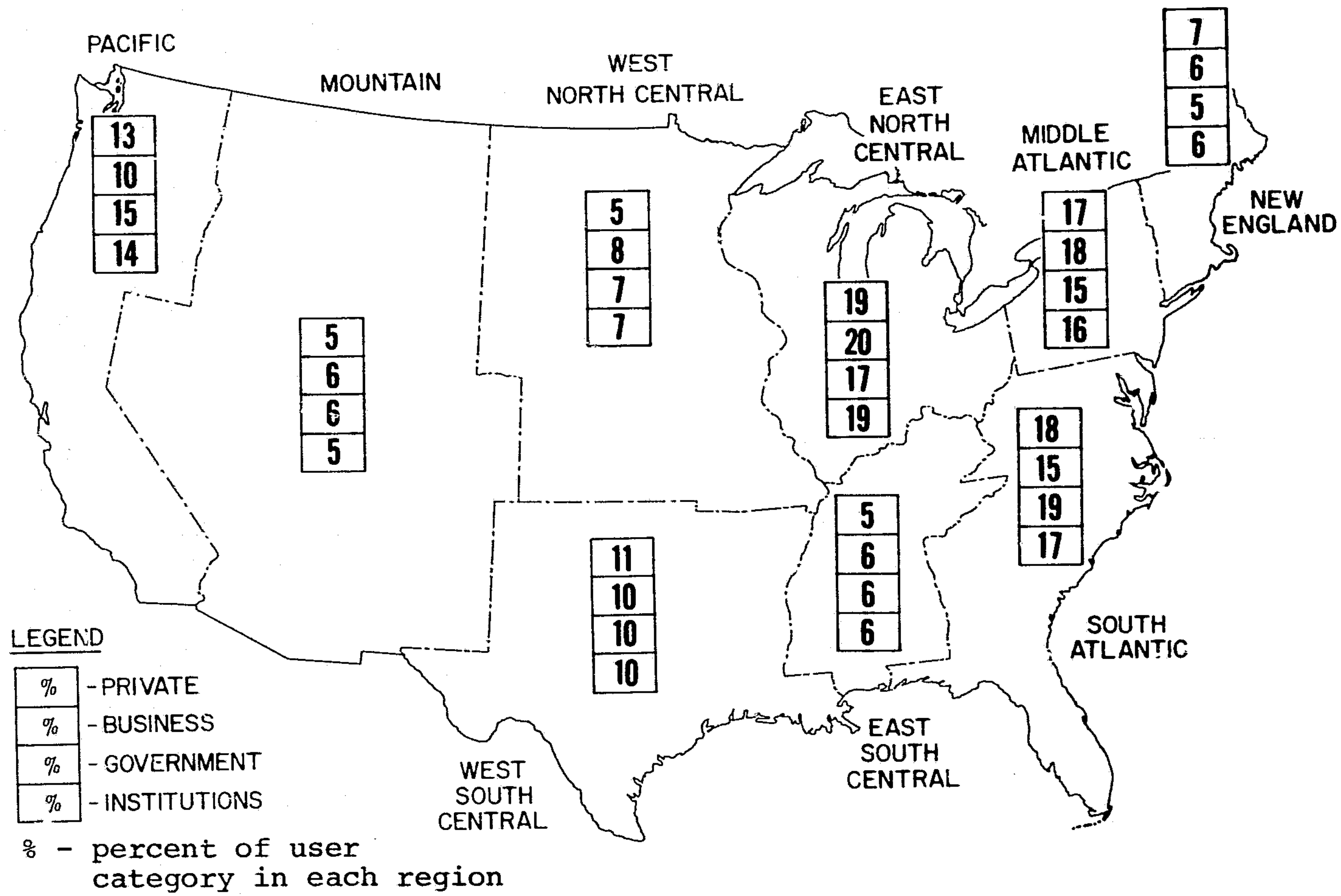

FIGURE 3.3-8. REGIONAL DISTRIBUTION OF DATA TRAFFIC FOR 1990 BY USER CATEGORY

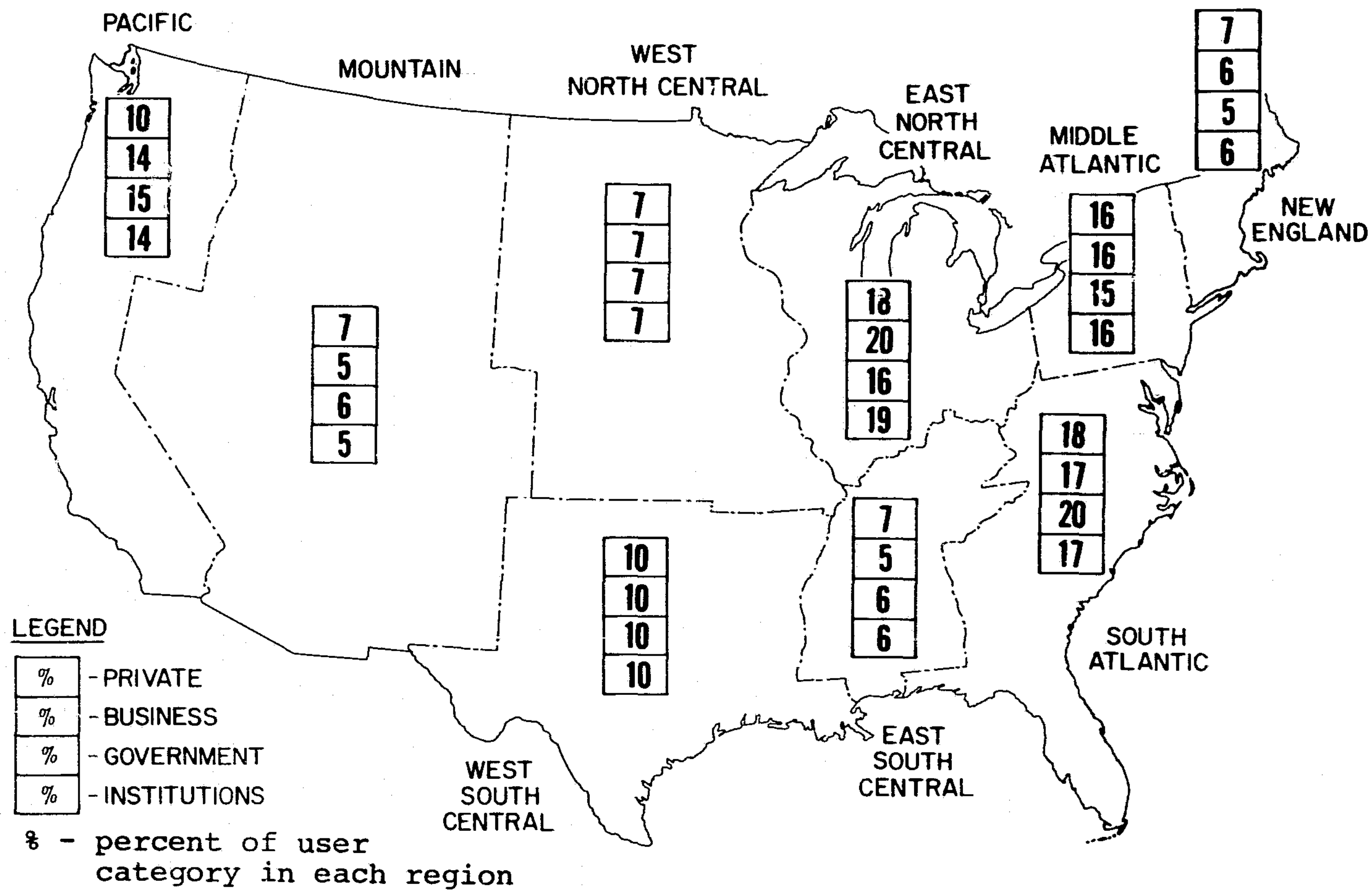

FIGURE 3.3-9. REGIONAL DISTRIBUTION OF DATA TRAFFIC FOR 2000 BY USER CATEGORY

TABLE 3.3-3. DATA TRAFFIC DISTRIBUTION BY REGION AND USER CATEGORY

Region	Private		Business		Government		Institutions		Total	
	%	Tr	%	Tr	%	Tr	%	Tr		
(a) Data - 1980										
New England	-	-	6	5	5	1	6	1	6	7
Middle Atlantic	-	-	18	14	16	3	17	3	18	20
East North Central	-	-	20	15	17	4	19	3	20	22
West North Central	-	-	8	6	8	2	8	1	8	9
South Atlantic	-	-	15	11	18	4	16	2	15	17
East South Central	-	-	6	5	6	1	6	1	6	7
West South Central	-	-	10	7	10	2	10	2	10	11
Mountain	-	-	6	5	6	1	5	1	6	7
Pacific	-	-	10	7	14	3	13	2	11	12
Total	-	-	67	75	19	21	14	16	100	112
(b) Data - 1990										
New England	7	.2	6	11	5	3	6	2	5	16
Middle Atlantic	17	.5	18	35	15	8	16	6	18	50
East North Central	19	.6	20	38	17	9	19	7	20	55
West North Central	5	.2	8	16	7	4	7	2	8	22
South Atlantic	18	.5	15	28	19	10	17	6	16	45
East South Central	5	.2	6	11	6	3	6	2	6	16
West South Central	11	.3	10	19	10	5	10	4	10	28
Mountain	5	.2	6	11	6	3	5	2	6	16
Pacific	13	.3	10	19	15	8	14	5	11	32
Total	1	3.0	67	188	19	53	13	36	100	280
(c) Data - 2000										
New England	7	.3	6	17	5	4	6	3	6	24
Middle Atlantic	16	.6	16	47	15	13	16	9	16	70
East North Central	18	.7	20	59	16	13	19	11	19	84
West North Central	7	.3	7	20	7	6	7	4	7	30
South Atlantic	18	.7	17	50	20	17	17	10	18	78
East South Central	7	.3	5	15	6	5	6	3	5	23
West South Central	10	.4	10	29	10	8	10	6	10	43
Mountain	7	.3	5	15	6	5	5	3	5	23
Pacific	10	.4	14	41	15	12	14	8	14	62
Total	1	4.0	67	293	19	83	13	57	100	437

(Tr = Traffic in thousands of terabits per year)

4.0 CASE STUDY OF A METROPOLITAN AREA

This section describes the communications environment of a large metropolitan area. A detailed description of the existing communications plant, and related geographic, demographic, and economic factors, is presented and the likely development of the region in terms of communications is projected through the year 2000.

The Atlanta region was selected for this study as being one of economic growth with rapidly expanding needs for communications technology. The development of communications patterns in this region is typical of those for many U.S. urban areas characterized by substantial growth in population and in economic activity.

To obtain an overview of the communications facilities configuration within the Atlanta area and of the current and projected traffic demand, a site visit was made. Demographic, economic, traffic, and communications facilities data was collected from the Atlanta Regional Planning Commission, the Atlanta Board of Trade, and from the major communications common carriers situated in the area. This information was supplemented with information obtained from FCC, USITA, REA, AT&T, and other industry publications referenced in this section.

4.1 BACKGROUND INFORMATION

The Atlanta Region, as defined for the purposes of this study, consists of the following counties: Clayton, Cobb, DeKalb, Douglass, Fulton, Gwinnett, and Rockdale. It coincides with the local Atlanta free-calling area, the largest such area in the country.

The Atlanta Region is situated in the North Georgia Area covered by the telephone Numbering Plan Area (NPA) 404. Figure 4.1-1 shows an outline map of Georgia locating the Atlanta Region and NPA 404.

The area of the Atlanta Region is somewhat less than that of the 17 county (recently increased from 15) Atlanta SMSA, but contains about 90 percent of its population and employment. The population of the Atlanta Region in 1976 was 1.6 million. As illustrated in Figure 4.1-2 this is expected to grow to 3.5 million by the year 2000. Clearly Atlanta is a rapidly growing city. The current annual growth of about five percent is six times the national average. Moderating but high growth rates are projected throughout the period of this study (Ref. 4.1-1).

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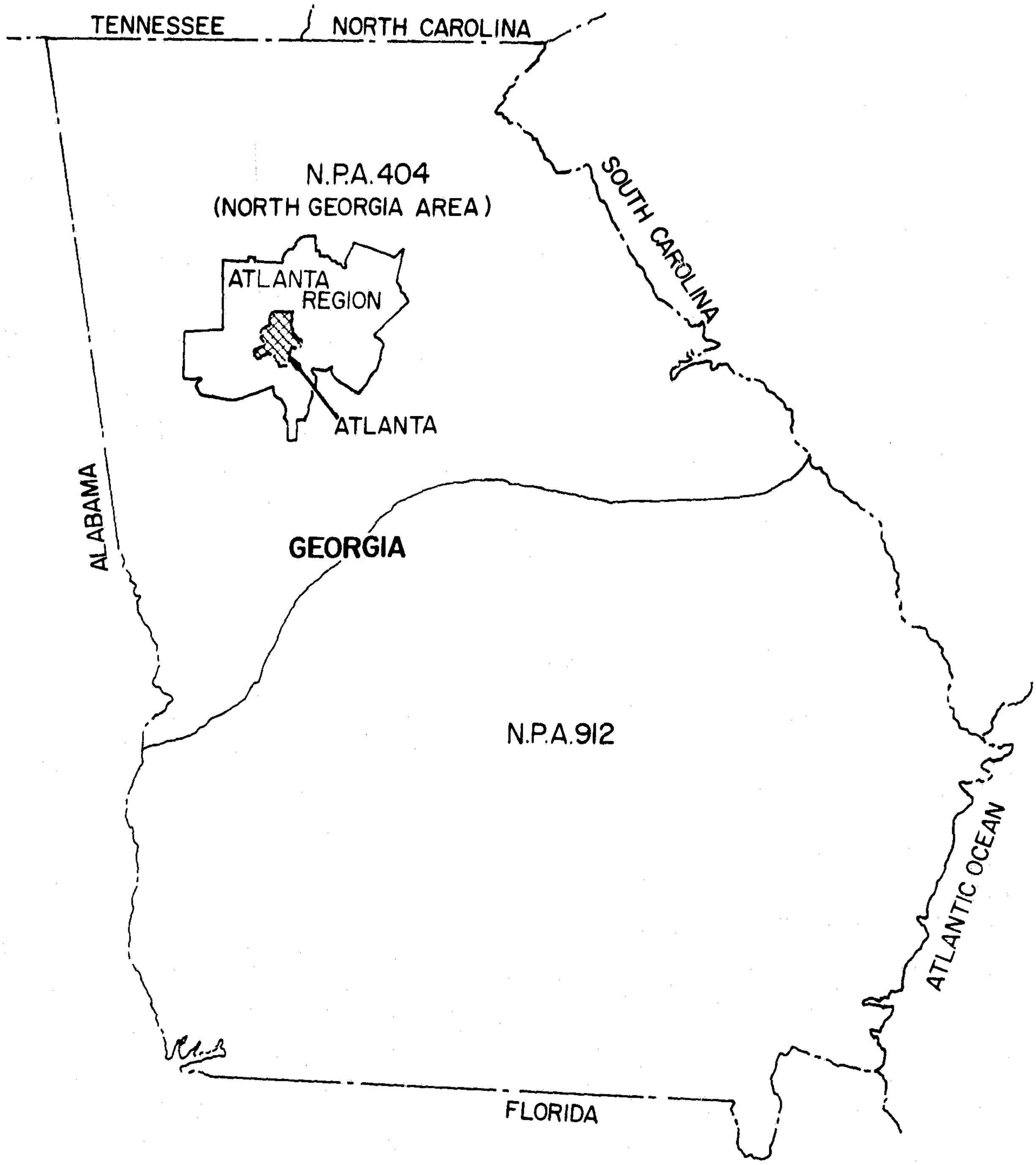


FIGURE 4.1-1. MAP OF GEORGIA AND ATLANTA REGION

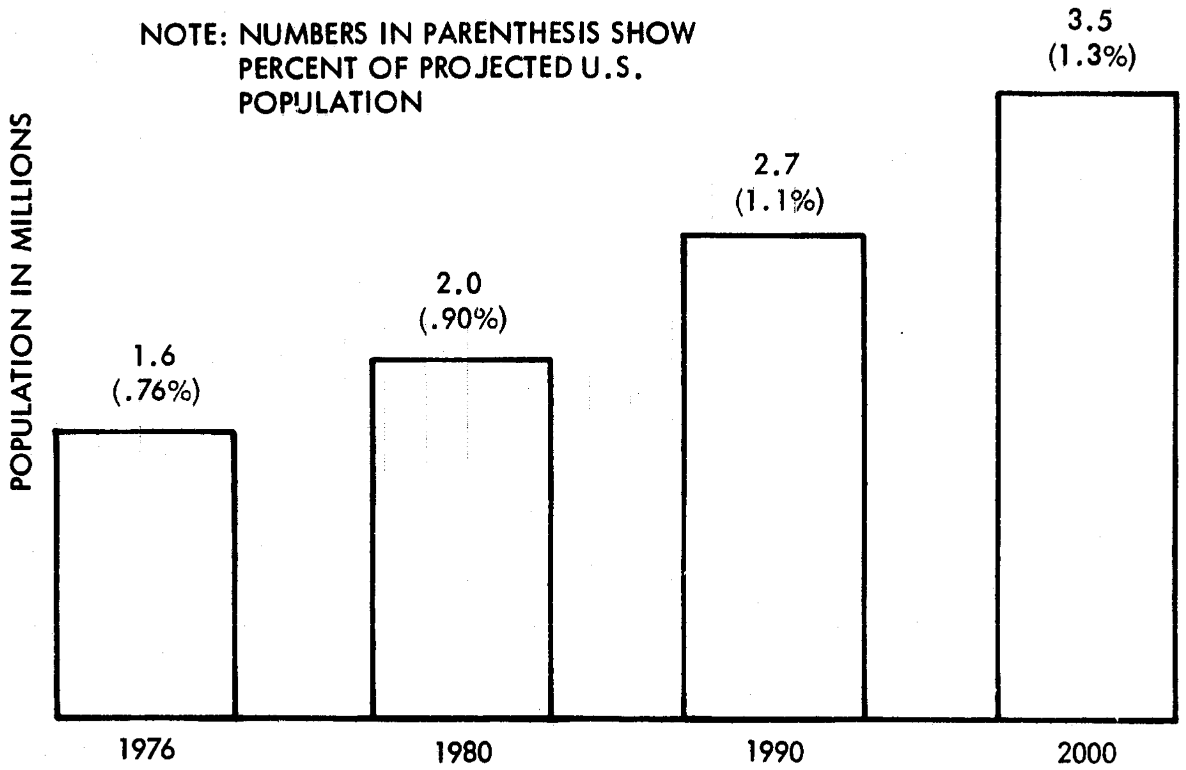


FIGURE 4.1-2. POPULATION FORECASTS FOR THE ATLANTA REGION

In 1976, employment in the Atlanta Region was approximately 720,000 with projected growth as shown in Figure 4.1-3 to 1580 by the year 2000 (Ref. 2.1-8). Current annual growth rate is 4.5 percent which is again considerably higher than the national average of 2.5 percent.

According to the Regional Development Plan produced by the Atlanta Regional Commission (Ref. 4.1-1), the population of the Atlanta Region is highly concentrated in the central city. But, during the two decades between 1980 and 2000, the trend of population movement will be towards de-centralization and the population will redistribute itself over surrounding areas, requiring expansion of communications facilities to serve these areas.

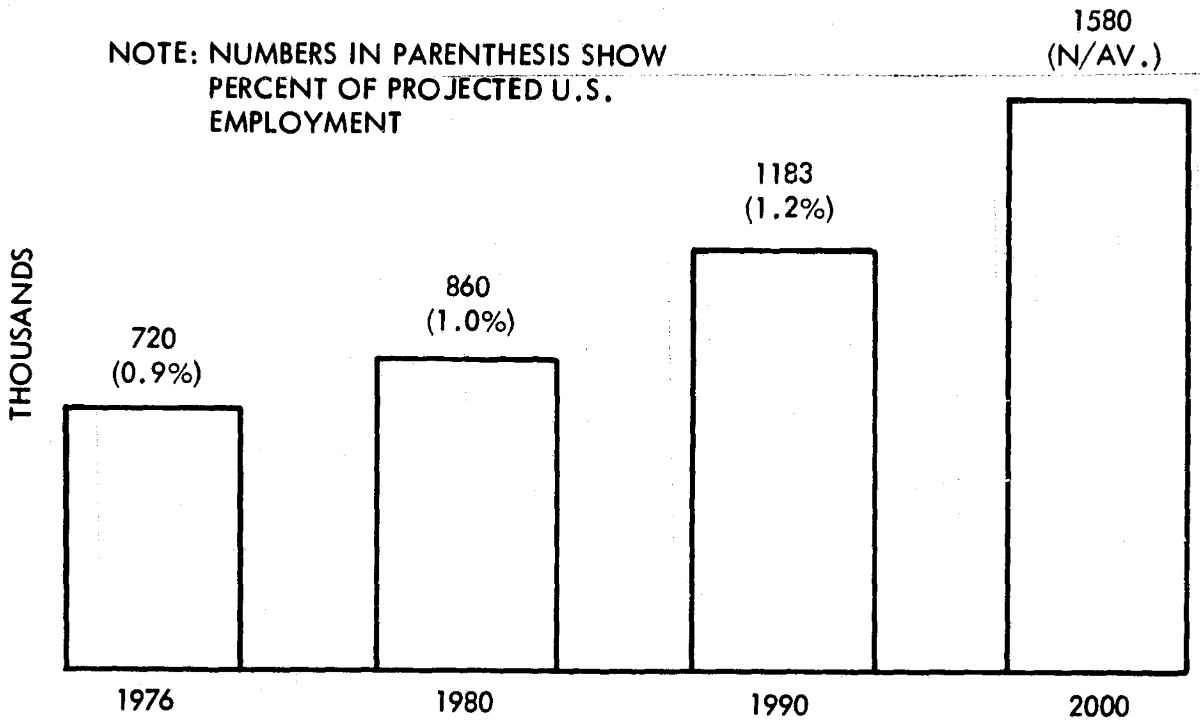


FIGURE 4.1-3. TOTAL EMPLOYMENT PROJECTIONS

Transportation for the Atlanta Region is provided by an extensive freeway and rapid transit system. This expanding system is shown in Figure 4.1-4.

Commercial and industrial development is widespread throughout the Atlanta Region. Figure 4.1-5 shows the current distribution of industrial and office parks and shopping centers (Ref. 4.1-1).

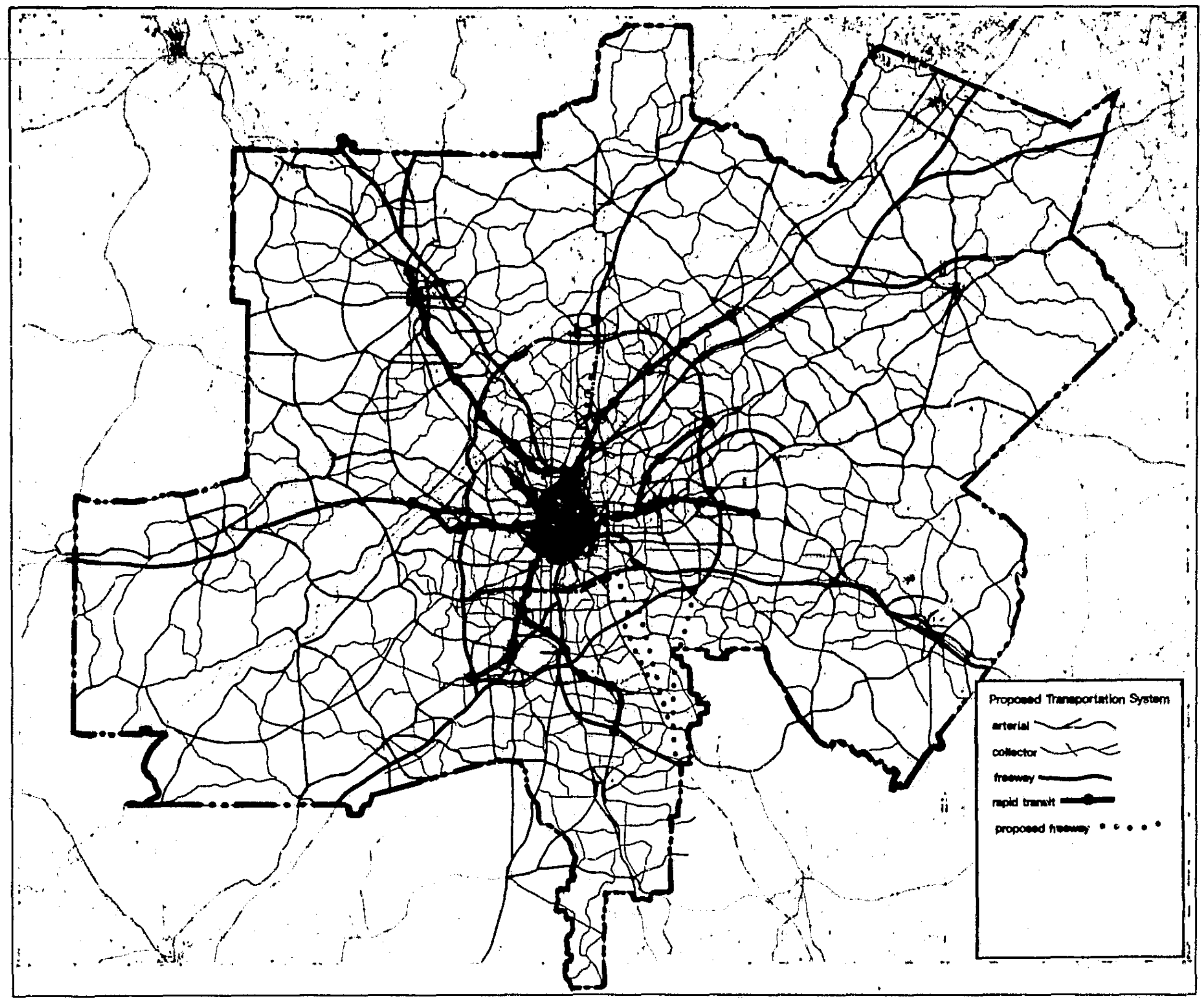


FIGURE 4.1-4. ATLANTA REGION MASS TRANSIT
AND FEEDER ROAD SYSTEMS

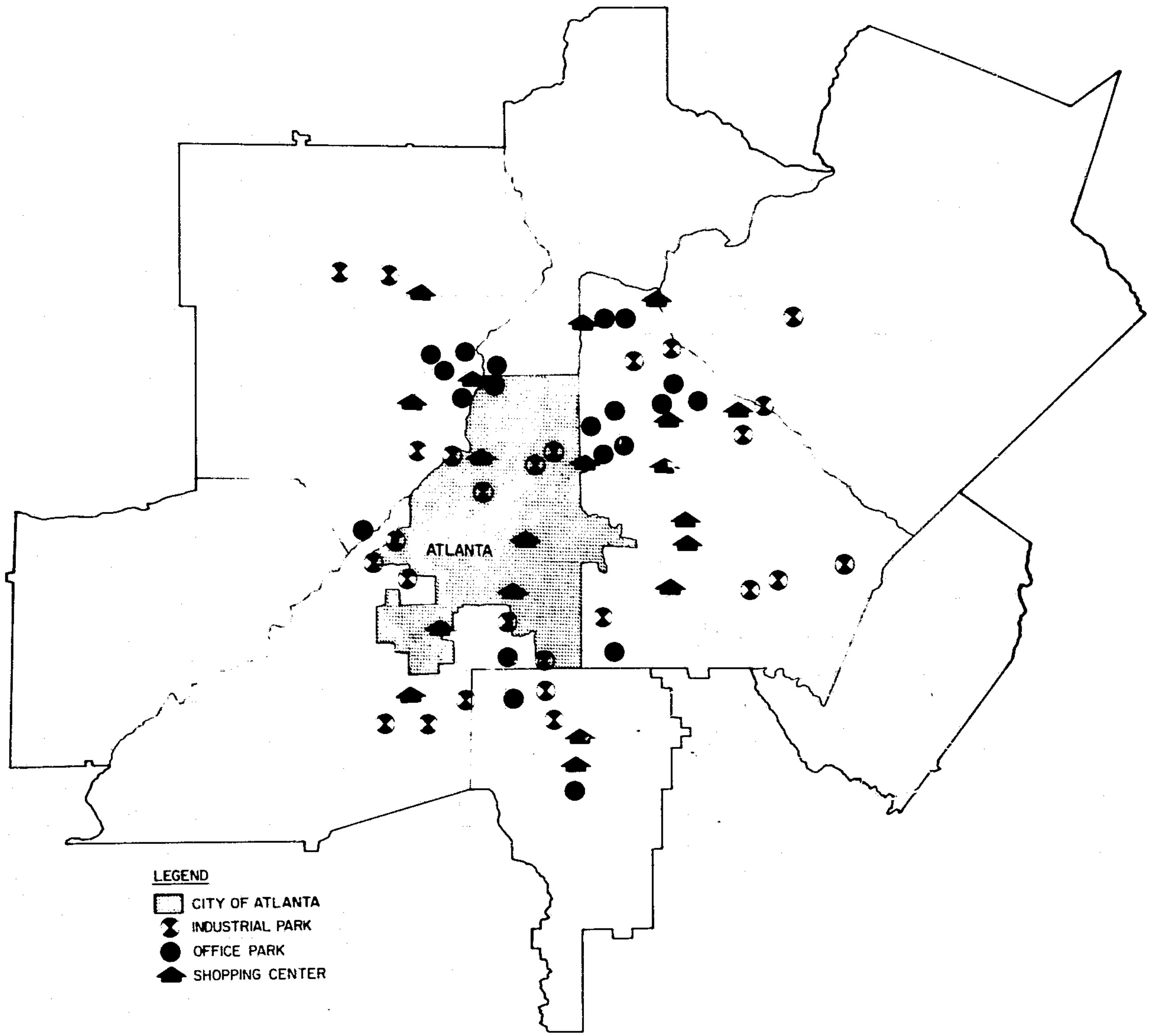


FIGURE 4.1-5. ATLANTA REGION COMMERCIAL AND INDUSTRIAL DISTRIBUTION

4.2 EXISTING AND PROJECTED COMMUNICATIONS FACILITIES

This section describes the principal communications facilities serving the Atlanta Region and the North Georgia area.

Wire centers* and local interoffice trunks are considered local facilities and are described for the Atlanta Region. Long haul facilities, such as microwave line-of-sight and coaxial cable (L carrier), are described for the North Georgia area covering Numbering Plan Area 404.

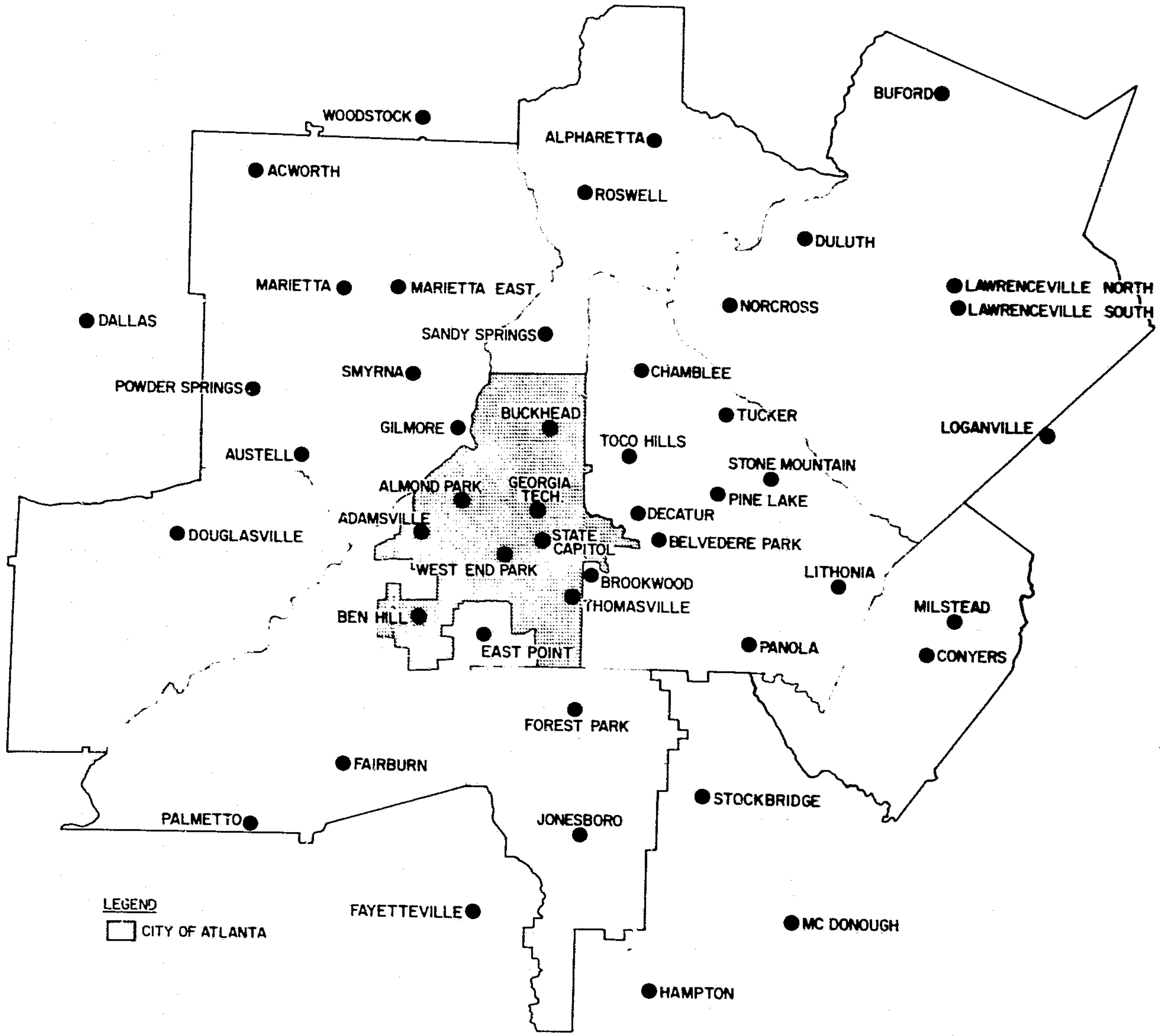
4.2.1 WIRE CENTERS

The Atlanta Region is served by a variety of trunking facilities which interconnect approximately 50 wire centers. The approximate location of these wire centers, obtained from the Southern Bell Telephone Company, is shown in Figure 4.2-1. (For security reasons, the wire center configuration shown differs slightly from the actual configuration.)

The number of main telephones (lines) per wire center for the base year 1978, and projections to the year 2000, are shown in Table 4.2-1. The data for 1978 was obtained from the Southern Bell Telephone Company during the Atlanta site visit. Since the number of lines per wire center was not directly available, the estimates were based on demographic data and the number of office codes assigned.

The projections for 1980, 1990, and 2000 are based on annual growth rates for centers located in the inner city (low growth rate) and in the outlying areas (high growth rate). The first 31 centers in Table 4.2-1 (Buford through Woodstock) are located in the outer areas and the remaining 17 (Buckhead through Sandy Springs) in the inner city area. The 1978-1980 annual growth rate given by Southern Bell is 4.2 percent for the inner city wire centers, and 19.5 percent for the suburban wire centers. Figures presented in this table are rounded to the nearest thousand.

*"Wire centers" are replacing the commonly encountered "Community Dial (Class 5) Office" which is limited to a single exchange code and 10,000 lines. A modern wire center housing large, program-controlled switches, may handle considerably more than 10,000 lines and may include several three-digit exchange codes.



Note: Locations are approximate

FIGURE 4.2-1. ATLANTA REGION WIRE CENTER CONFIGURATION

TABLE 4.2-1. NUMBER OF MAIN TELEPHONES PER WIRE CENTER

	MAIN STATIONS (IN THOUSANDS)(1)			
	1978	1980	1990	2000
Buford	2	3	9	23
Alpharetta	1	1	4	12
Roswell	12	17	52	139
Duluth	1	1	9	12
Norcross	12	17	52	139
Chamblee	40	57	173	462
Lawrenceville North	10	14	43	115
Lawrenceville South	10	14	43	115
Loganville	1	1	4	12
Tucker	35	50	151	404
Stone Mountain	10	14	43	115
Lithonia	1	1	4	12
Milstead	1	1	4	12
Conyers	10	14	43	115
Panolia	10	14	43	115
Stockbridge	2	3	9	23
McDonough	1	1	4	12
Hampton	2	3	9	23
Jonesboro	35	50	151	404
Fayetteville	6	9	26	69
Palmetto	2	3	9	23
Fairburn	6	9	26	69
Douglasville	12	17	52	139
Austell	15	21	65	173
Powder Springs	2	3	9	23
Dallas	1	1	4	12
Smyrna	40	57	173	462
Marietta	15	21	65	173
Marietta East	15	21	65	173
Acworth	1	1	4	12
Woodstock	2	3	9	23
Buckhead	30	33	50	93
Toco Hills	30	33	50	93
Decatur	30	33	50	93
Belvedere Park	30	33	50	93
Brookwood	30	33	50	93
Thomasville	30	33	50	93
State Capitol	30	33	50	93
Georgia Tech	30	33	50	93
Gilmore	30	33	50	93
Almond Park	30	33	50	93
Adamsville	30	33	50	93
West End Park	30	33	50	93
Ben Hill	30	33	50	93
East Point	30	33	50	93
Forest Park	30	33	50	93
Pine Lake	30	33	50	93
Sandy Springs	30	33	50	93
Total	823	1003	2207	5196

(1) Figures rounded to nearest thousand

4.2.2 LOCAL TRUNKING

At the present time the wire centers listed in Table 4.2-1 are interconnected primarily by multipair cable. It is evident that requirements are beginning to exceed the current cable trunking facilities, a condition expected to grow more serious in subsequent years. To provide more trunking facilities to carry the growing local interoffice traffic, digital PCM transmission over copper pairs (T carrier) and fiber optic cables are being considered. This paragraph describes the existing local trunking configurations and the projected augmentation or replacement of selected facilities by fiber optic cable in 1980, 1990, and 2000.

Originating and terminating traffic between pairs of wire centers was computed on the basis of the information supplied by the Southern Bell Telephone Company, supplemented by additional typical traffic information obtained from AT&T, REA, and internal ITT sources. Telephone usage ranging from 2.2 CCS (100 Call-Seconds) per main station in semi-rural areas to eight CCS per main station in industrial and metropolitan areas was assumed with an average value of five CCS per main station being selected as representative of a metropolitan region such as Atlanta. An analysis of traffic in large free-calling areas showed that originating and terminating traffic volumes are approximately equal and represent a nominal 80 percent of the total traffic. Outgoing traffic was assumed to be distributed among destination offices in proportion to their size. Tandem traffic was excluded.

The number of trunks required between pairs of wire centers was calculated, using a computer model resident at the ITT North America Telecommunications Division in Des Plaines, Illinois. An end-to-end grade of service of 0.01 (one lost or blocked call out of 100) was assumed. The resulting local trunking configuration and typical cross sections (circuits per trunk route) of selected routes in the northwest sector of the Atlanta Region are shown in Figure 4.2-2 for 1980, 1990, and 2000.

Since 1970 virtually all inter wire center facility additions have been made using PCM carrier on paired copper cable. Based on the anticipated traffic growth in the Atlanta Region, it is estimated that the capacity of existing paired copper cables will begin to be exhausted in the 1985-1987 time period, especially in the maximum growth cross sections. For very short interoffice trunks, with moderate circuit cross sections, adding T carrier over existing copper pairs remains a viable means of increasing trunking capacity. Consequently, T carrier is being actively implemented in the Atlanta intra-urban wire centers.

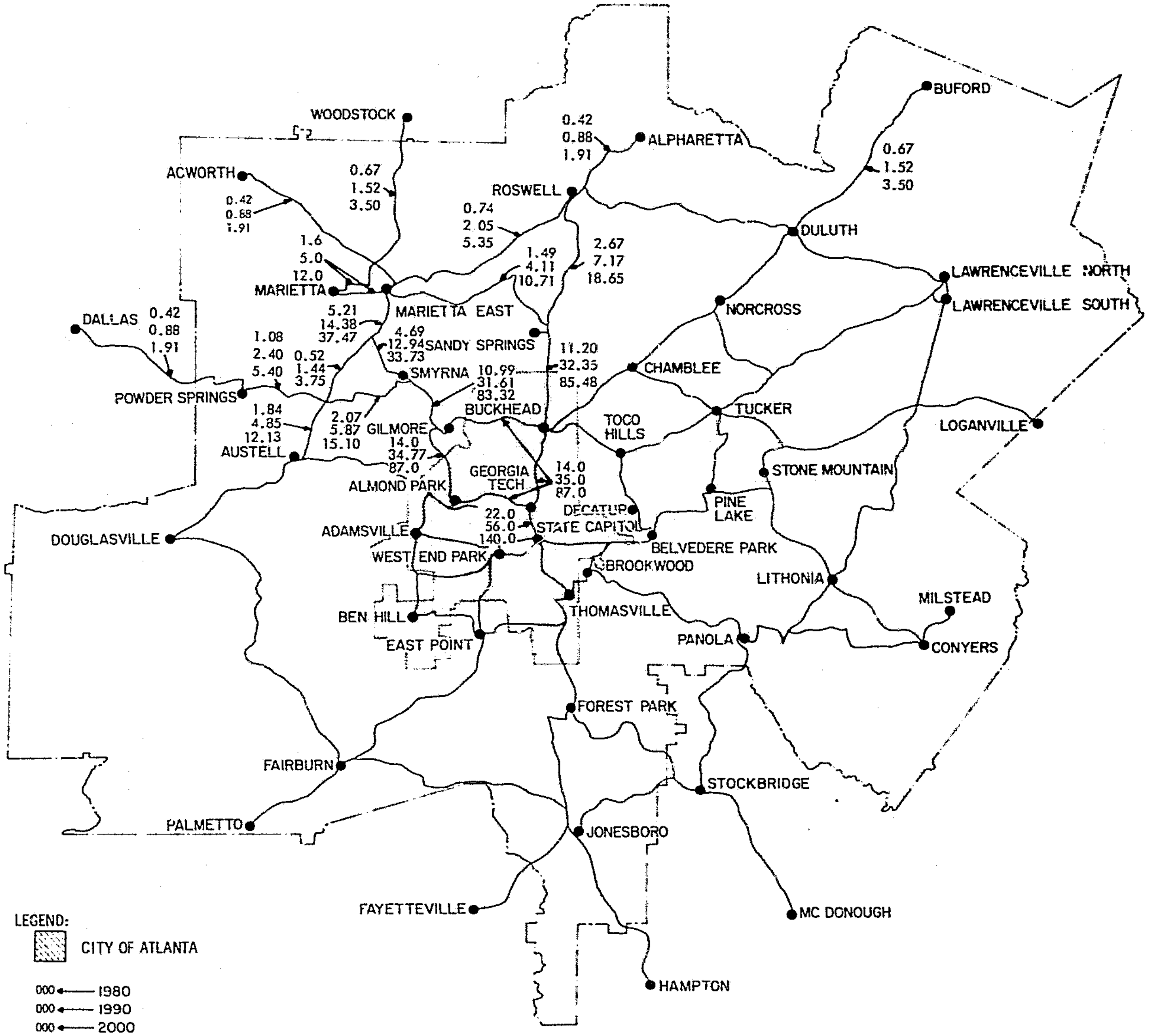


FIGURE 4.2-2. ESTIMATED TRUNK CROSS SECTIONS - 1980, 1990 AND 2000

However, for longer distances, particularly those leading out of the inner city into the suburban areas, and for those portions of the interoffice trunking network lying in the suburban areas, fiber optics is rapidly becoming the more economical alternative. Implementation of fiber optics trunking has already begun in the Atlanta Region with an eight-mile link being installed by the Western Electric Company for operational use in 1980. This link will have a capacity of one T-3 channel (45 Mbps) to accommodate high density trunking and will be operated by the Southern Bell Telephone Company.

A projected fiber optics overbuild of the local trunking network is shown in Figures 4.2-3 through 4.2-5 for 1980, 1990, and 2000, respectively. This estimate is based on the trunking capacities shown in Figure 4.2-2 for the northwest quadrant of the Atlanta Region. For the other quadrants, circuit requirements were scaled on the basis of proportionality between wire center size and corresponding circuit requirements as computed for the northwest quadrant.

C-3

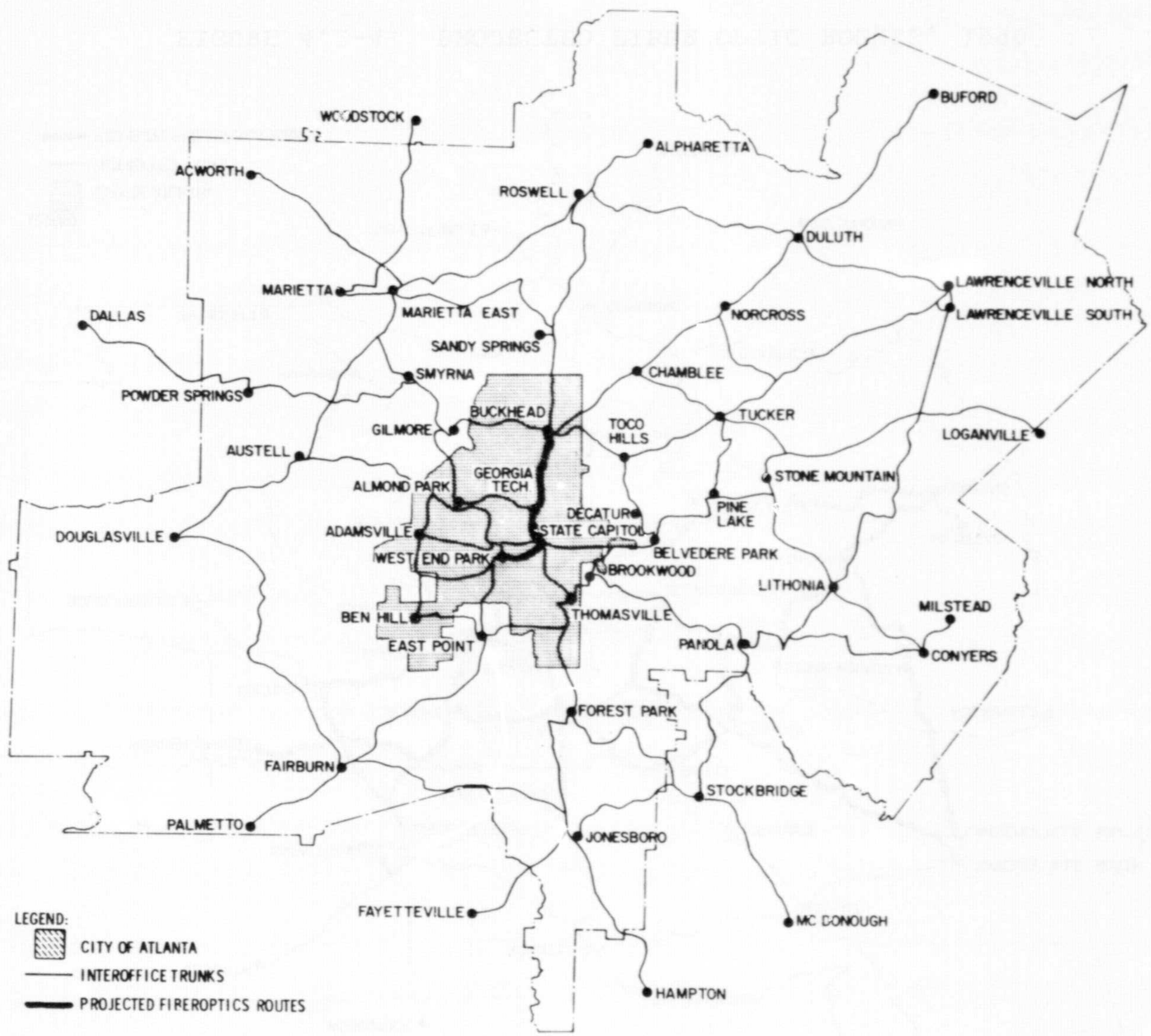


FIGURE 4.2-3. PROJECTED FIBER OPTIC ROUTES, 1980

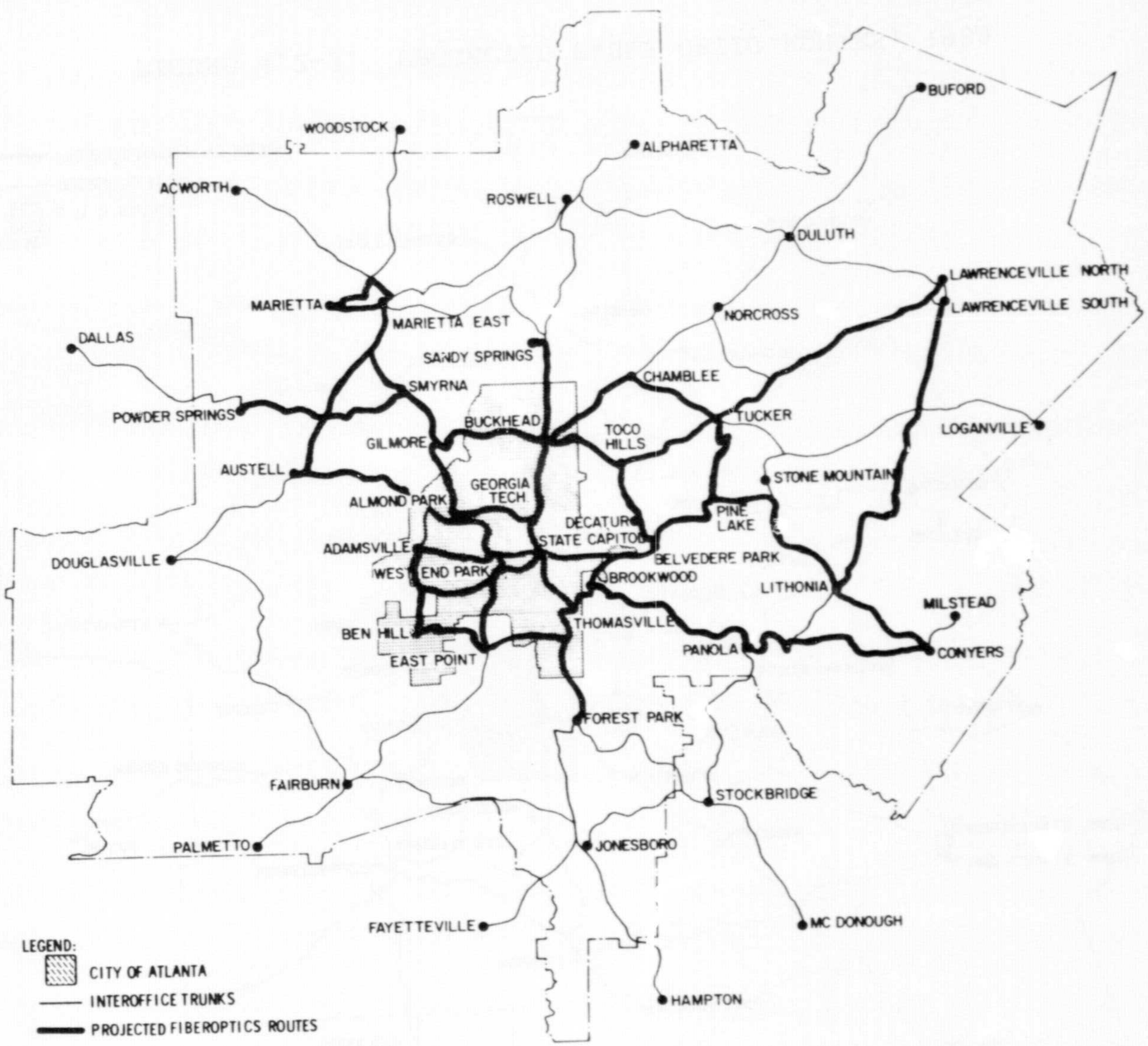


FIGURE 4.2-4. PROJECTED FIBER OPTIC ROUTES, 1990

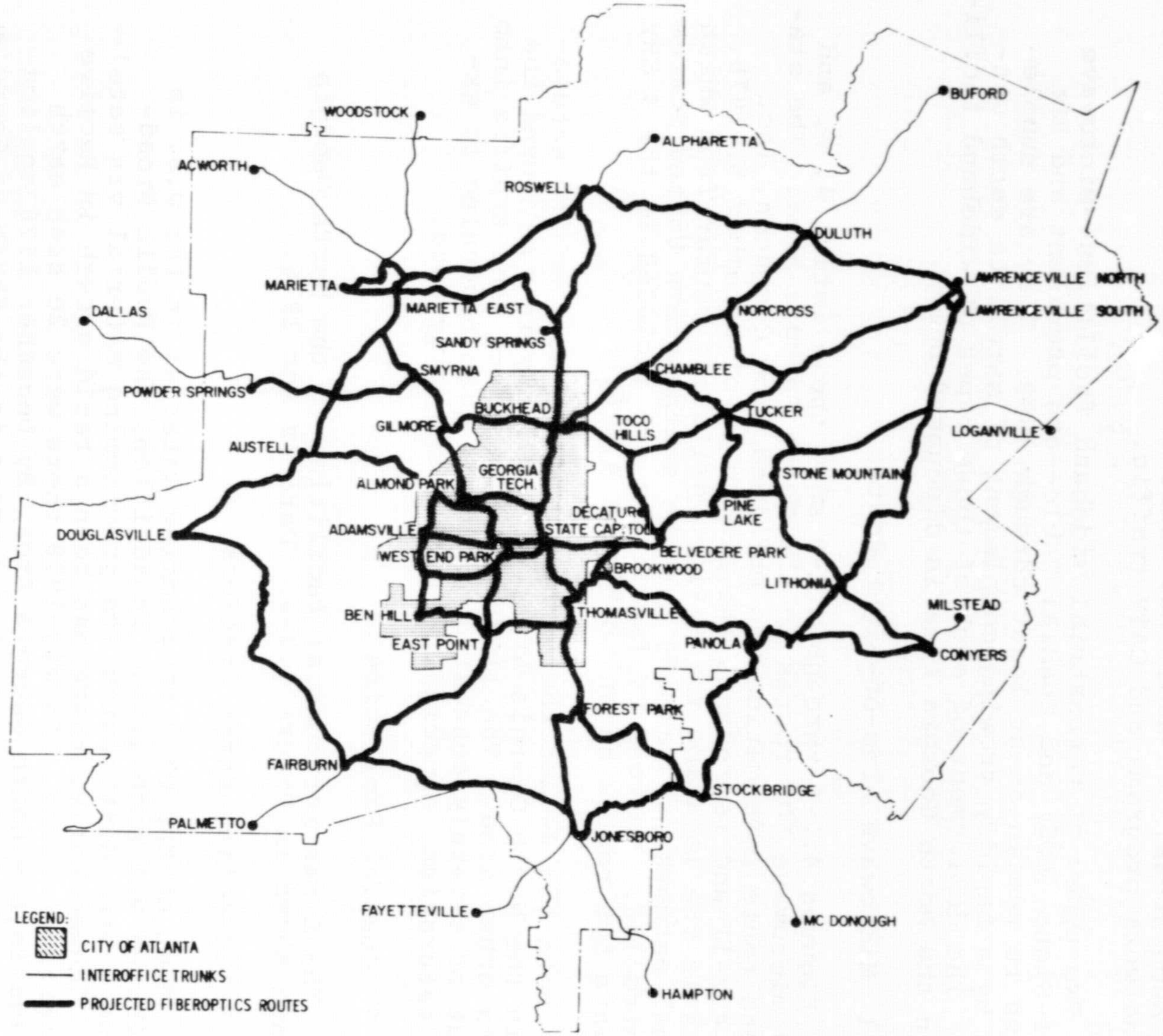


FIGURE 4.2-5. PROJECTED FIBER OPTIC ROUTES, 2000

4.2.3 WIDEBAND FACILITIES

Wideband facilities are used primarily to carry intermediate and long distance, voice and data traffic between urban areas and to distribute this traffic to major switching centers within such areas. In addition, these facilities are used to carry network programs and CATV traffic.

Two types of terrestrial wideband facilities--Microwave Line-of-Sight (LOS) and Coaxial Cable--are prevalent and are expected to remain so at least through 1990. They are supplemented by a rapidly growing complement of satellite earth stations. The deployment of each of these types of wideband facilities in the North Georgia Area is discussed below.

4.2.3.1 Microwave Line-of-Sight Routes

Figures 4.2-6 through 4.2-8 show the existing 4, 6, and 11 GHz microwave LOS routes in the North Georgia Area. The station and route information was obtained from Compucon, Inc. (Ref. 4.2-1) and represents the status as of December 5, 1978. Atlanta is the location for a video switching center from which regional network programming for the southeastern United States is controlled. Network TV facilities are included in the 4-GHz microwave LOS routes shown in Figure 4.2-6.

Both the 4- and the 6-GHz bands are approaching saturation in the North Georgia Area, particularly in and around the Atlanta urban area. The 11-GHz band, used to feed traffic into and out of severely congested nodes, is also beginning to exhibit saturation, especially in the inner city area.

4.2.3.2 Coaxial Facilities

The L carrier coaxial facilities in the North Georgia Area are shown in Figure 4.2-9. Data is for 1976.

4.2.3.3 Satellite Earth Stations

Most of the CATV programming material in the U.S. is distributed via satellite. In addition, the Public Broadcasting System distributes its programming material via satellite. Consequently, there has been a rapid growth in Receive Only earth stations. In mid-1978 there were 20 such earth stations in the North Georgia Area. By December 1978 applications for 50 stations were in progress in the State of Georgia. Figure 4.2-10 shows most of the existing Receive Only and Transmit/Receive earth stations (Ref. 4.2-2).

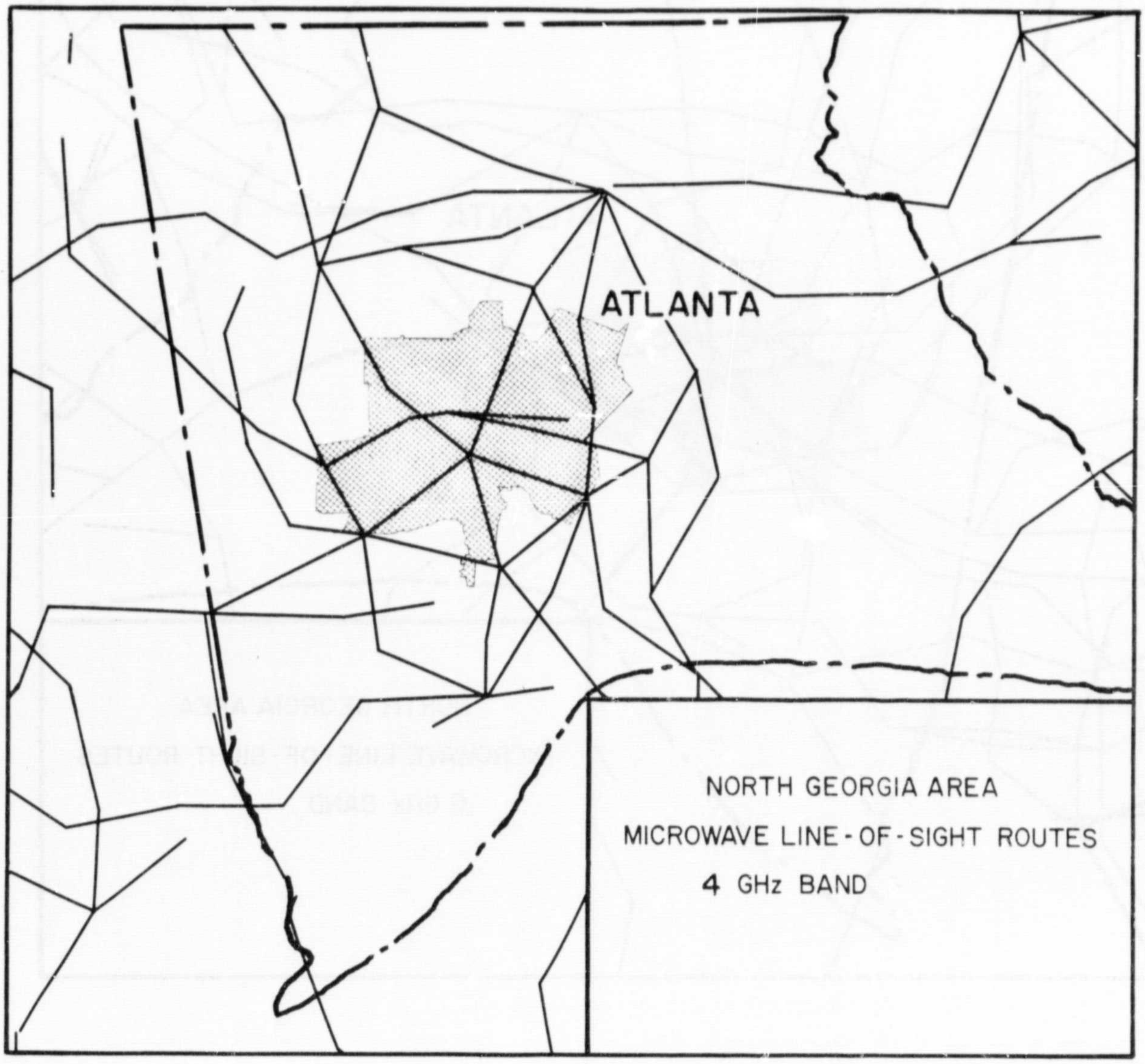


FIGURE 4.2-6. MICROWAVE LINE OF SIGHT ROUTES IN NORTH GEORGIA AREA - 4 GHz BAND

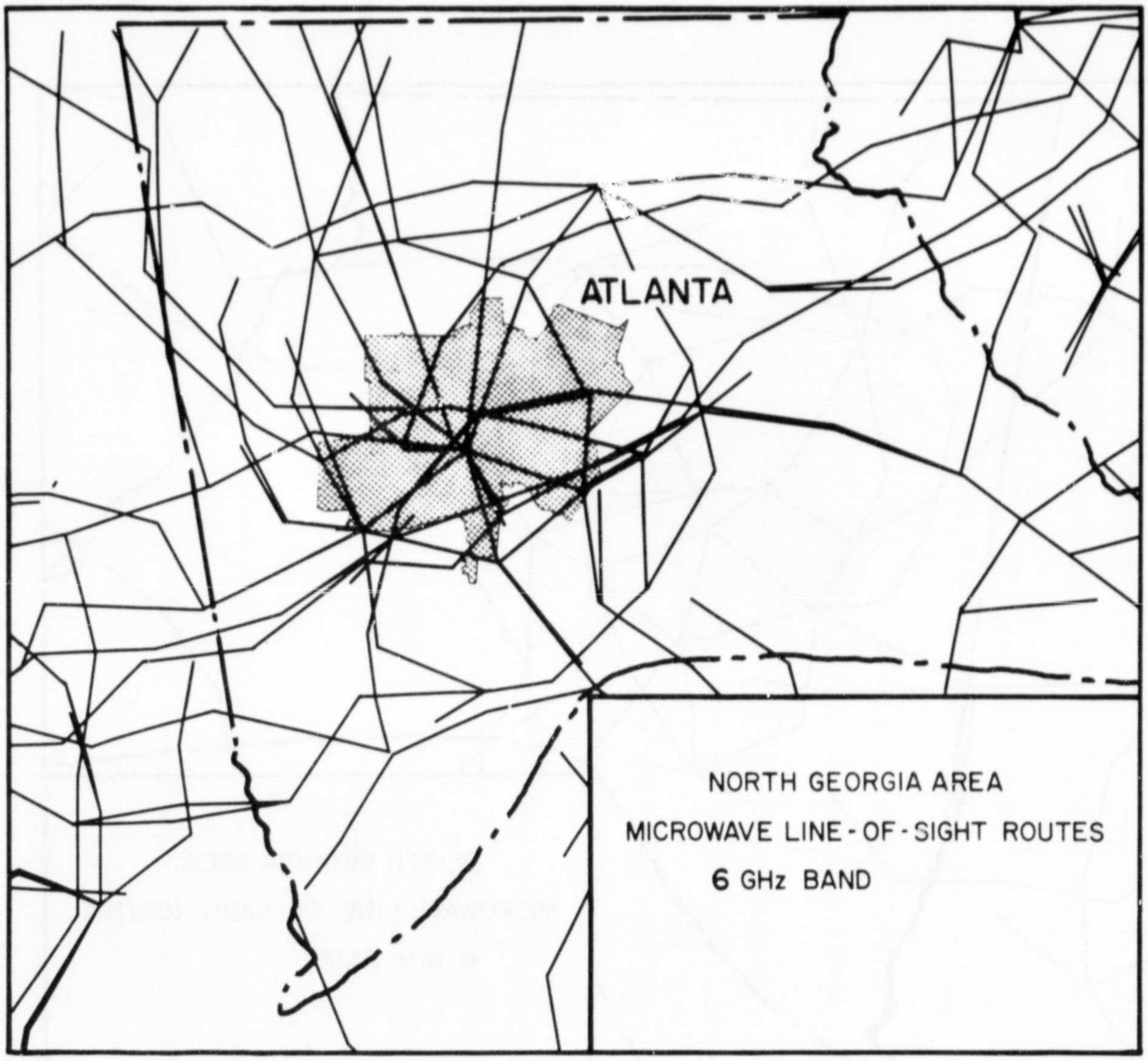


FIGURE 4.2-7. MICROWAVE LINE OF SIGHT ROUTES IN NORTH GEORGIA AREA - 6 GHz BAND

FIGURE 4.2-8. MICROWAVE LINE OF SIGHT ROUTES IN NORTH GEORGIA AREA - 11 GHz BAND

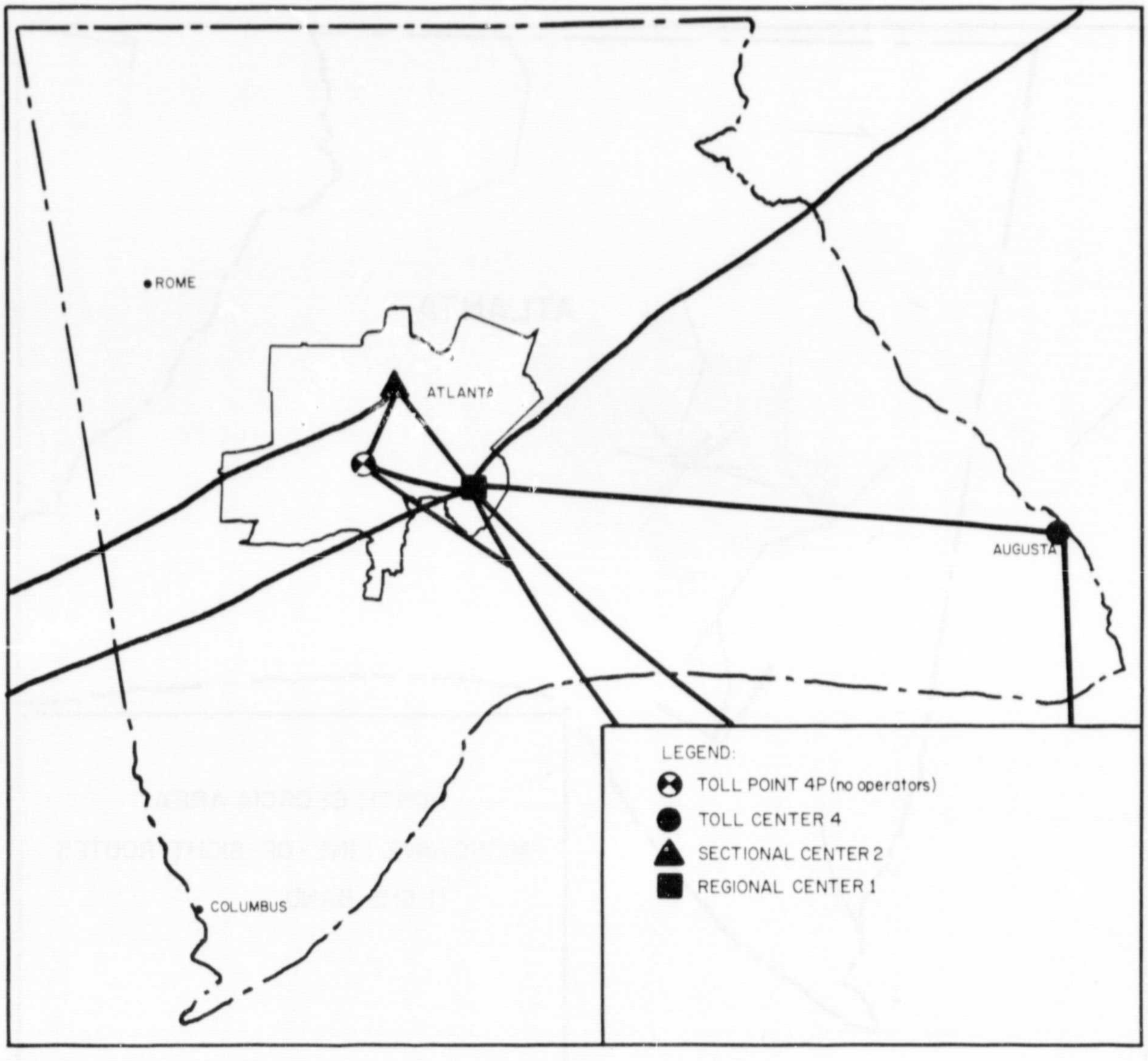


FIGURE 4.2-9. COAXIAL FACILITIES (L CARRIER) IN NORTH GEORGIA AREA

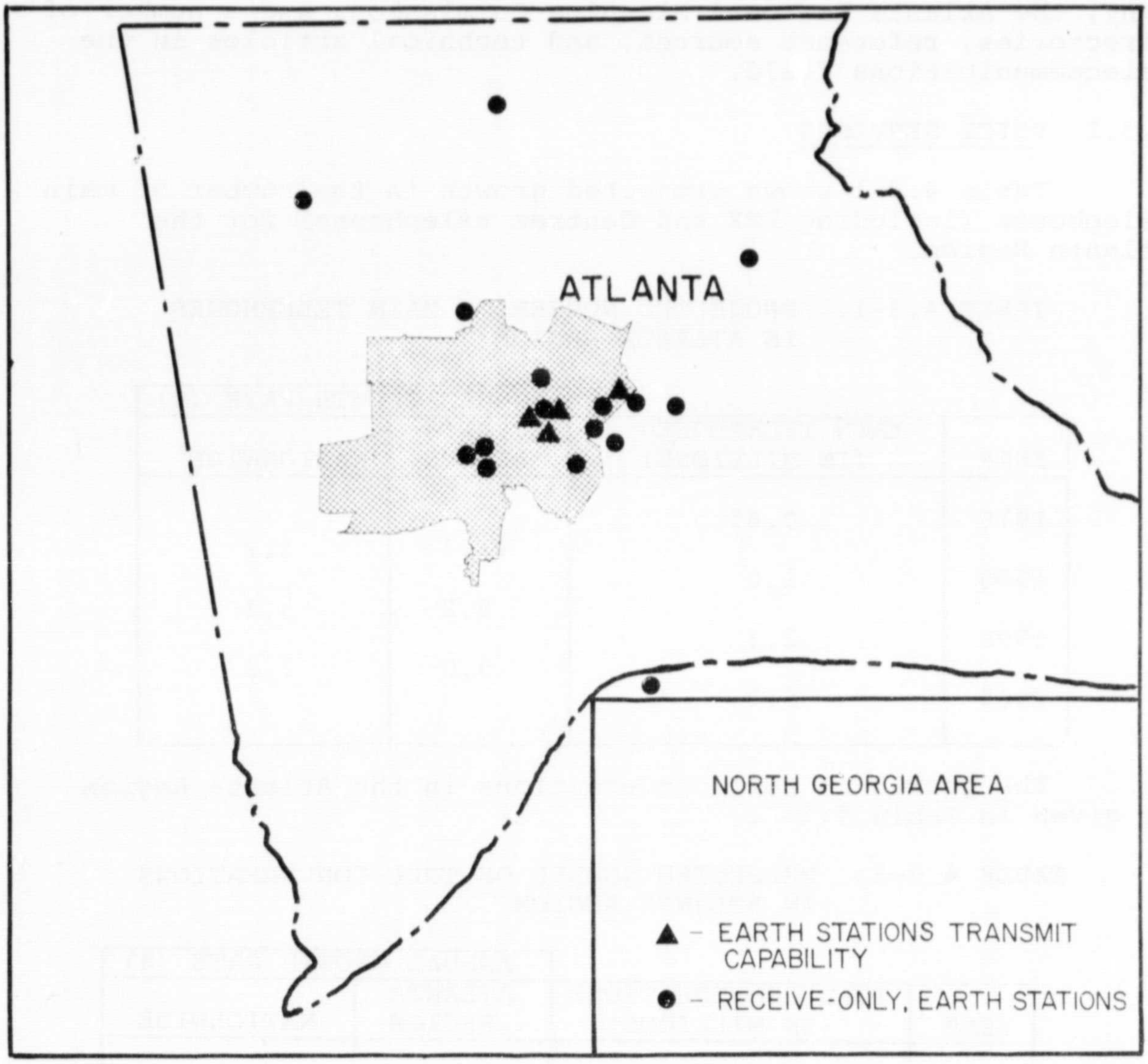


FIGURE 4.2-10. EXISTING EARTH STATIONS IN NORTH GEORGIA AREA

4.3 DEMAND FORECASTS FOR THE ATLANTA REGION

This section presents demand projections for selected services in the Atlanta Region. The data presented is based on information obtained from the Southern Bell Telephone Company, the Atlanta Regional Planning Commission, and a number of directories, reference sources, and technical articles in the telecommunications field.

4.3.1 VOICE SERVICES

Table 4.3-1 shows projected growth in the number of main telephones (including PBX and Centrex telephones) for the Atlanta Region.

TABLE 4.3-1. PROJECTED NUMBER OF MAIN TELEPHONES IN ATLANTA REGION

YEAR	MAIN TELEPHONES (IN MILLIONS)	ANNUAL GROWTH RATE (%) ATLANTA REGION	NATIONWIDE
1976	0.65		
		11.4	3.2
1980	1.0		
		8.2	3.1
1990	2.2		
		9.0	2.2
2000	5.2		

The growth in toll conversations in the Atlanta Region is given in Table 4.3-2.

TABLE 4.3-2. PROJECTED NUMBER OF TOLL CONVERSATIONS IN ATLANTA REGION

YEAR	TOLL CONVERSATIONS (IN MILLIONS)	ANNUAL GROWTH RATE (%) ATLANTA REGION	NATIONWIDE
1976	0.18		
		9.6	8.8
1980	0.26		
		8.4	9.0
1990	0.58		
		9.1	7.0
2000	1.38		

The growth rate for the number of main telephones in the Atlanta Region (which starts from a relatively low base) is approximately triple that for the United States as a whole. The corresponding growth rates in toll conversations for the Atlanta Region, however, are projected to be only slightly higher than the national average. In general, the number of main telephones tends to follow population statistics while the number of toll calls appears to be linked more closely with economic growth.

4.3.2 VIDEO SERVICES

Atlanta offers a rapidly expanding base for business activities. The presence of major corporate offices and the existence of at least one CATV superstation indicates that demand for video services will be high.

Table 4.3-3 projects the number of CATV subscribers in the Atlanta Region. Present penetration of the market is about 12 percent, but is projected to grow to close to 90 percent by the year 2000.

TABLE 4.3-3. PROJECTED NUMBER OF CATV SUBSCRIBERS IN THE ATLANTA REGION

YEAR	POTENTIAL SUBSCRIBERS (THOUSANDS)	ACTUAL SUBSCRIBERS (THOUSANDS)	MARKET PENETRATION
1976	873	100	11.5%
1980	950	150	15.8%
1990	1100	500	45.5%
2000	1300	1150	88.5%

This large pool of potential and actual subscribers will result in a substantial number of CATV systems supported by Receive-Only earth stations and local wideband distribution facilities. Table 4.3-4 projects the number of CATV systems and Receive-Only earth stations expected for the Atlanta Region.

TABLE 4.3-4. PROJECTED CATV RECEIVE-ONLY EARTH STATIONS IN ATLANTA REGION

YEAR	1980	1990	2000
EARTH STATIONS	20	24	30

Videoconferencing is expected to grow in the Atlanta Region at least as fast as the national average. Based on projected employment statistics, the Atlanta Region can be expected to utilize about 100,000 videoconference hours per year by the year 2000.

The University System of Georgia consists of 30 institutions widely dispersed throughout the State. Two of these are situated in Atlanta. Additionally there are 35 private institutions of higher education in Georgia, 11 of which are in Atlanta. Atlanta therefore can be expected to form a hub for Educational Video activities in the State.

Similarly, because of Atlanta's position as State Capitol, the Atlanta Region will be responsible for much of the public affairs wide band transmission in Georgia.

4.3.3 DATA SERVICES

The projected growth of various new and special data services is based partially on information collected during the Atlanta field visit, and partially on the results of a study performed at Bell Telephone Laboratories to evaluate the economics of an all-digital telephone exchange network for a mix of telecommunication services expected to evolve in the 1980s.

The services, or equipment providing these services, are shown in Figure 4.3-1 and represent the following capabilities:

(a) Smart Telephones

Real time selective call acceptance
Home banking and EFT
Limited electronic document reception
Remote meter reading and energy management
Security systems

(b) Low Speed Interactive Graphics Telephones

Desk top information systems
Character-oriented electronic mail systems

(c) Slow Scan Video telephones

Home video library
Video shopping from home
Education

(d) Facsimile

(e) High Speed Data (above 9600 bps)

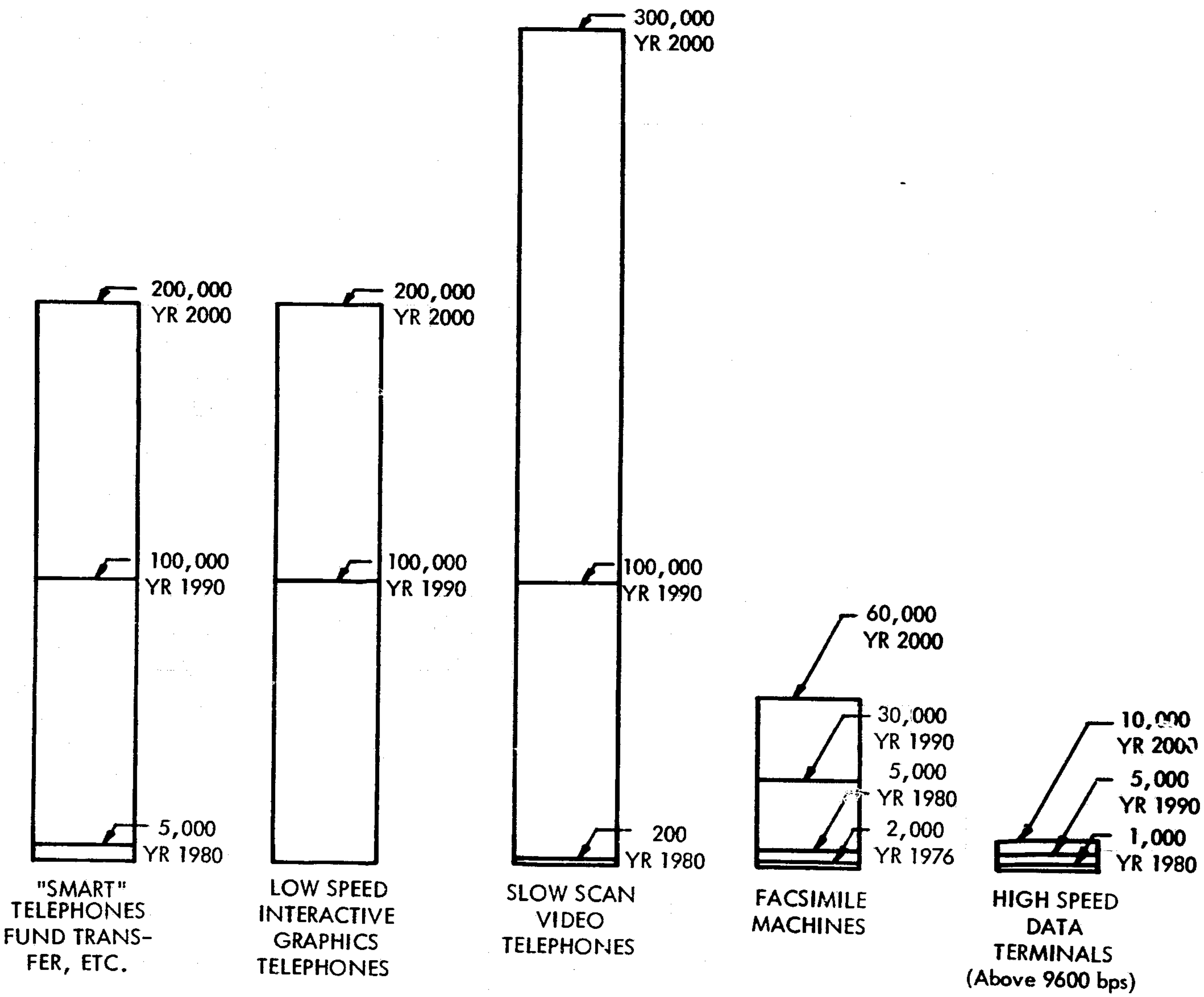


FIGURE 4.3-1. GROWTH OF NEW DATA SERVICES IN THE ATLANTA REGION

4.3.4 INTERSTATE TRUNKS

Figure 4.3-2 shows the number of interstate trunks connecting Atlanta with 39 other major SMSAs in 1978. In 1978 there were a total of 6904 such trunks, representing approximately three percent of all trunks between these SMSAs. These figures are based on data obtained from a 40-city traffic matrix developed from AT&T-supplied call completion reports. Figures 4.3-3 through 4.3-5 show the projections of these trunk quantities to 1980, 1990, and 2000 respectively.

FIGURE 4.3-2. ATLANTA TELECOMMUNICATIONS COMMUNITY OF INTEREST, 1978

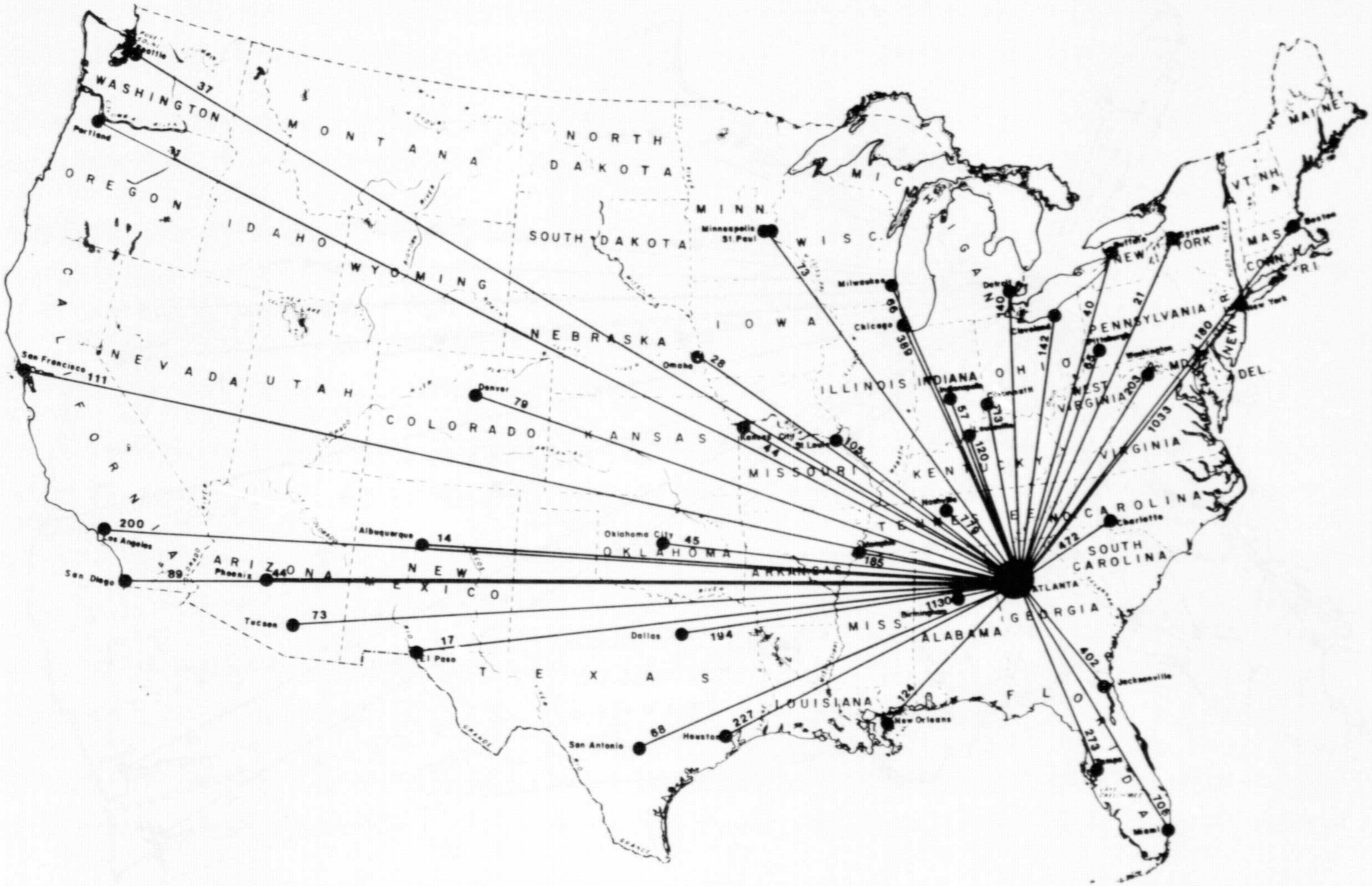


FIGURE 4.3-3. ATLANTA TELECOMMUNICATIONS COMMUNITY OF INTEREST, 1980

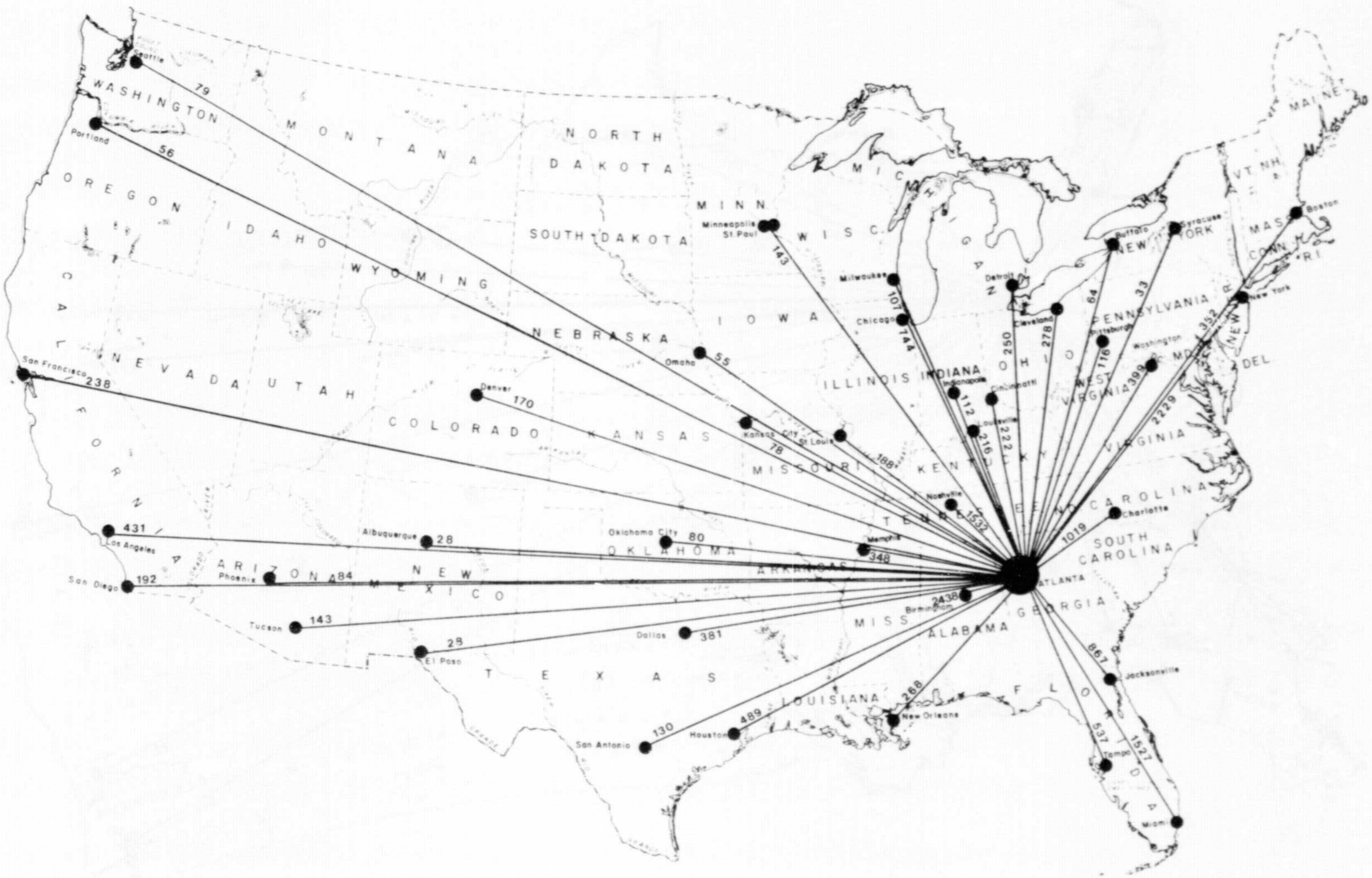


FIGURE 4.3-4. ATLANTA TELECOMMUNICATIONS COMMUNITY OF INTEREST, 1990

FIGURE 4.3-5. ATLANTA TELECOMMUNICATIONS COMMUNITY OF INTEREST, 2000

4.4 SATELLITE POTENTIAL

As indicated previously, the Atlanta Region represents 0.8 percent of the total U.S. population in 1976, growing to 1.3 percent in 2000. The Atlanta Region's share of the total U.S. civilian employment was 0.9 percent in 1976 and is projected to become 1.2 percent in 1990, the last year for which U.S. employment projections are available. The projected growth rate of population, employment and most communications facilities and services in the Atlanta Region is markedly higher than the corresponding U.S. average growth rates.

It is reasonable to expect, therefore, that the Atlanta Region's share of the U.S. satellite capacity will exceed its share of population.

Considering that the trunks connecting Atlanta with 39 other major SMSAs represent approximately three percent of the interstate trunks interconnecting the 40 SMSAs, and that the Atlanta Region appears to be well prepared for video-capacity local and interoffice distribution, three percent may be taken as a reasonable estimate of the Atlanta Region's share of the total U.S. transponder requirements projections for the years 1980-2000.

5.0 TRANSMISSION COST AND CAPACITY

Subsections 5.1 and 5.2 deal with the cost of terrestrial transmission media. Microwave radio relay and coaxial cable are the predominant terrestrial media currently used by domestic carriers. The analysis also investigates the cost of the newly emerging medium of fiber optics cables, which will become increasingly more attractive as an alternative to microwave radio and coaxial cable.

Subsection 5.1 analyzes the terrestrial media from the viewpoint of a potential competitor to a 30/20 GHz satellite system. That is, the investigation concentrates on the use of these terrestrial media for long haul communications. Subsection 5.2, on the other hand, is concerned with the use of the terrestrial media to support the short haul requirement of a satellite system by providing an interconnecting link between an earth station and the main communication distribution point, such as a telephone company central office. Short haul terrestrial systems are also needed to provide an interconnecting link between two earth stations employed to provide increased reliability by means of space diversity.

Subsection 5.3 deals with the problem of total usable capacity available for domestic communications satellites in the C and Ku band. The use of C and Ku band satellites is limited by permissable orbital spacing and transponder capacity. Also, international agreements determine how much of the available capacity can be used by United States carriers. Subsection 5.3 provides an estimate of the number of transponders available for domestic transmission in each band.

5.1 TERRESTRIAL COMMUNICATIONS COSTS - LONG HAUL

This subsection estimates the cost for long-haul terrestrial transmission facilities for the years of 1980, 1990, and 2000. The following subsection estimates the corresponding costs for the shorthaul circuits which are used for local distribution between the long-haul facilities and the user locations, and between diversity earth station sites.

The cost of terrestrial communications facilities includes the cost of transmission, switching, trunk, and line equipment. Also, a significant component of the cost is the physical plant necessary to house the equipment, towers to mount line-of-sight antennas, ducts for cables, prime power generators, and other such ancillary facilities and equipment. These areas are considered in this subsection in deriving present and projected terrestrial communications costs.

The current domestic terrestrial long-haul communications plant is dominated by microwave line-of-sight radio relay and coaxial cable systems. It is anticipated that the future will see the growth of fiber optics as an important high capacity substitute for conventional coaxial cable and, therefore, this third media is also included in the terrestrial cost analysis.

The cost analyses given in this subsection are expressed in constant 1976 dollars. That is, anticipated fluctuations of the dollar, inflation, and similar economic factors are not considered in order to present a lear view of the relation of the cost for one medium compared to another to permit relative comparisons to be made.

5.1.1 ASSUMPTIONS

The general assumptions that frame the service cost study are as follows:

a) In some areas of the cost analysis, Bell System statistics have been used solely as representative of the domestic terrestrial communication system. The full range of terrestrial media used in this country is encompassed within the Bell System operating plant and, therefore, little accuracy is lost by this assumption.

b) The baseline year selected for the cost analysis is 1976 since comprehensive statistics are available for this period.

c) The overall cost of terrestrial based communications depends on the assumed mix of terrestrial media projected for the subject year. For example, in the later years of concern to the study, (i.e., 1990-2000), fiber optics becomes an important constituent of the terrestrial facility mix, although it is not significant during the earlier years. The postulated media mix is used to derive a composite average service cost since this is the basis of the carrier's tariffs. This is the result of the fact that the assignment of facilities is usually the prerogative of the carrier and not that of the user. Certainly for the switched services, the selection of interswitch trunks is determined by the route selection at the switching office and not by user preference.

d) Terrestrial facilities are assumed to be engineered for equal availabilities, irrespective of connectivity, medium, or network configuration. An end-to-end (user-to-user) availability of a circuit, whether voice, data, or video, is assumed to be approximately 0.999, signifying an outage time of around nine hours per year, a figure of merit characteristic of North American service.

e) Average circuit-mile lengths for long-haul voice, data and video services are kept constant from 1976 through 2000 in the cost calculations. For voice and data services, the average circuit length is 890 miles; for video services, 500 miles. In the case of video, the circuit length assumption is

based on an FCC estimate for commercial television. In the case of voice and data, the estimate was based on AT&T Long Lines statistics for 1976.

5.1.2 COST METHODOLOGY

A number of methodologies exist among telecommunications common carriers to establish a base for service cost assessment. Invariably each costing approach must lead to a rationale which yields the establishment of that service's revenue requirements. The term "cost" bears several meanings relative to the "user." The "subscriber" of a service pays a service charge to the carrier of that service. The charge is based on an established rate or tariff which is developed by the carrier. Public utilities commissions approve intrastate rates and tariffs, while the FCC governs interstate matters. Common carriers can also be users of services by leasing facilities from other carriers at established tariffs and, in turn, providing tariffed services to their users. The Internal Record Carriers are good examples of this type of common carrier. In general, tariffs applicable to other common carriers provide prices discounted from those available to end users. In essence, however, the underlying basis for any tariffed service is the cost to the carrier for providing that service, and this is the cost developed in this section.

The basic method applied in the study was first to examine costs on a macroscopic level, i.e., taking all costs for interstate telecommunications facilities and putting them on an annual basis. Existing plant in service at some point serves as a benchmark in estimating overall costs. Because the total United States telephone plant exceeds $100 billion, its very magnitude creates an inertia that pales the significance of year-to-year additions and retirements. Tariffs may shift rapidly, but costs do not. Because services share certain common facilities, allocation procedures must be applied to derive the cost of that service. For example, MTS and private line voice circuits share many common facilities, forcing the analyst to exercise care in allocating costs to each service. Similarly, switched and private line data services, particularly below 9.6 Kbps, are handled almost entirely by the existing telephone plant. All costs are projected on the basis of constant 1976 dollars to avoid complications arising from attempts to predict inflation trends.

5.1.2.1 Base Year Statistics

Terrestrial service costs used in this analysis are primarily based on the cost of 1976 facilities since comprehensive data is available for this year. The prime sources used in developing the cost analysis are:

Telephony's Directory, 1978-1979 issue, Telephony Publishing Corp. (Ref. 5.1-1)

The World's Telephones as of January 1, 1977, AT&T Long Lines (Ref. 5.1-2)

FCC Docket 18128 (Ref. 5.1-3)

FCC Docket 20814, Trial Staff Reports (Ref. 5.1-4)

Annual Statistical Report, Rural Telephone Borrowers, Calendar Year Ended December 31, 1976, REA Bulletin 300-4 (Ref. 5.1-5)

Statistics of Communications Common Carriers, FCC, Year Ended December 31, 1976 (Ref. 5.1-6)

FCC Report, Docket No. 19129, January 17, 1975 (Ref. 5.1-7)

Table 5.1-1 summarizes the more important statistics used in the cost analysis of the following paragraphs.

TABLE 5.1-1. U.S. TELECOMMUNICATIONS STATISTICS - 1976

	All Companies	Bell System
1. <u>COSTS IN BILLIONS OF DOLLARS</u>		
Total Comm. Plant - Net	82.9	77.1
Interstate	22.3 (Est.)	20.8
Total Operating Expenses	22.7	21.5
Interstate	7.1 (Est.)	6.6
2. <u>TRANSMISSION FACILITIES IN MILLIONS OF MILES</u>		
Telephone Carrier-Derived Channels	684	674
Interstate	450	444
Video Channels	0.139	0.122
Interstate	0.105	0.092
Coaxial Cable		
Total Tubes	0.384	0.339
Interstate Tubes	0.287	0.280
Interstate Equipped 4 KHz Circuits	165	153
Microwave Radio Relay		
Total Route Miles	0.184	0.118
Interstate Wideband Channels	0.976	0.907
Interstate Equipped 4 KHz Circuits	478	444
Fiber Optics		
Total Cables	-	-
3. <u>OTHER STATISTICS</u>		
Central Offices	20,020	17,512

A further breakdown of the interstate costs is given in Table 5.1-2. This is shown on a percentage basis to indicate the yearly change and to show the relative insensitivity of the cost structure to the yearly additions and retirement of plant.

TABLE 5.1-2. TELECOMMUNICATION PLANT COSTS - 1976

		Percentage	
a.	CAPITAL COSTS	100	
	Existing Interstate Costs		94
	Retirement of Facilities		3
	Additions to Plant		2
	Other Capital Costs		1
b.	GROSS PLANT	100	
	Depreciation Reserve		24
	Net Plant		76
c.	OPERATING EXPENSES	100	
	Maintenance		27
	Network Management		5
	General and Administrative		48
	Depreciation		20

Observation of Table 5.1-2 indicates that changes to plant amounted to only five percent of the total base in 1976. From this, one can deduce that the large capital investment in existing plant causes cost stability and, therefore, dramatic changes in costs cannot be expected.

5.1.2.2 Depreciation Schedules

To annualize the cost of assets for comparative purposes, the analysis establishes the weighted or aggregated depreciation schedule for facilities and derives the capital cost equivalent. Terrestrial circuits are designed to be operational for at least fifteen years, while satellites are usually designed for a seven year life, with earth stations extending to about fifteen years. Depreciation schedules used, based on expected economic life of the installed assets, are given in Table 5.1-3.

TABLE 5.1-3. DEPRECIATION SCHEDULES[1]

Equipment	Service Life (Years)
Buildings	35
Microwave towers	25
Central office equipment, crossbar	28
Central office equipment, electronic	25
Microwave electronic equipment	13
Aerial cable	22
Buried cable	28
Conduit and manhole	60
Station apparatus, telephone	11
Satellites	7
Earth stations, major (0-30 meters)	15
Earth stations, minor (5-8 meters)	5-10

(1) Source: Reference 5.1-8. Telephone Engineer and Management, April 15, 1978.

5.1.3 BASELINE COSTS PER CIRCUIT MILE - VOICE

Costs per circuit mile for voice services for the baseline year of 1976 are derived by dividing the total annualized cost by the number of interstate circuit miles. Table 5.1-4 presents the breakdown of plant investment by cost item and the percentage of the total represented by that item.

TABLE 5.1-4. PLANT INVESTMENT ON A CIRCUIT MILE BASIS (1976)

Cost Item	Investment per Circuit Mile ($)	Percent of Investment
Outside Plant	2.54	17.2
Central Office Equipment	9.73	65.8
Buildings	2.22	15.0
General Equipment	0.25	1.7
Other	0.05	0.3
TOTAL	14.79	100.0

The table shows that the total plant investment per circuit mile amounts to $14.79. Outside plant consists of a mix of transmission facilities including cable and radio relay. Central office equipment essentially includes switching equipment. General equipment includes station apparatus, PBXs and interface equipment.

In order to put the capital costs on an annual basis, it is necessary to determine the overall coverage life of the plant investment. Table 2-1, Volume 19 of FCC Docket No. 18128, dated January 13, 1978 (revised) (Reference 5.1-3) provides the data for making this determination, which is calculated as follows:

1. Annualized 1976 Investment $908 Million
2. Gross 1976 Investment $18,949 Million
3. Average Asset Life $\frac{(2)}{(1)} = \frac{\$18,949M}{\$908M} = 21$ Years

Annualized investment is calculated by taking the difference in reported annual costs ($6.464 billion) and total expenses ($5.556 billion).

Once the average asset life of the gross plant is derived as above, the part of the cost per circuit mile attributed to the plant investment proceeds as follows:

Annualized capital cost per circuit mile:

$$\frac{\text{Plant investment per circuit mile}}{\text{Average Asset Life}} = \frac{\$14.79}{21 \text{ yrs}} = \$0.70$$

Operating expenses are reported on an annual basis and, therefore, this part of the annualized cost per circuit mile can be calculated directly from reported carrier data as follows:

Annual operating expenses per circuit mile:

$$\frac{\text{Total annual operating costs}}{\text{Total circuit miles}} = \frac{\$1.548 \text{ billion}}{366\text{M circuit miles}}$$

$$= \$4.23 \text{ per circuit mile}$$

Both the 1976 operating costs and the total interstate circuit miles were obtained from AT&T Long Lines statistics.

The resultant total annualized cost per circuit mile is the sum of the annualized investment cost and operating cost:

$0.70/Circuit Mile + $4.23/Circuit Mile = $4.93/Circuit Mile

It should be noted that the total cost of $4.93 per circuit mile is expected to decline over the next twenty years at an average rate of one percent per year.

5.1.4 BASELINE COSTS PER CIRCUIT MILE - DATA

Domestic data traffic uses the conventional voice telephone network and specialized networks and facilities which are dedicated to data transmission. As of the base year 1976, specialized common carriers dedicated to data services (e.g., Telenet, Datran) served only a small part of the total domestic data traffic and, therefore, are insignificant to the base year calculation of the costs per circuit mile. The Bell System's Dataphone Digital System (DDS), however, is more significant, accounting for 28,800 circuits as shown in Table 5.1-5.

TABLE 5.1-5. DIGITAL TRAFFIC SERVICES

	No. of Circuits	No. of Circuit Miles
DDS	28,800	23,000,000
Wideband Data	1,060	502,000

The table also shows wideband data circuits, i.e., circuits handling data rates greater than 9600 bps, which amount to 1060 circuits with a total circuit mile count of 502,000. The total circuit miles for both DDS and wideband data, however, serve only a small part of the domestic data requirements of all users. The vast bulk of the data requirements in 1976 were handled via the conventional voice network on either a private line or a dial-up basis. Precise statistics on this component of telephone traffic are not available since it is difficult for the carriers to determine the subscriber's use of the line when telephone company modems are not employed. From the sale of modems and digital communicating terminals, however, it is apparent that the use of the conventional telephone network for data transmission in the baseline year is far more substantial than the use of specialized digital transmission services. We conclude, therefore, that the baseline cost per circuit mile for data services is essentially the same as that given above for voice, and the same values are used.

5.1.5 BASELINE COSTS PER CIRCUIT MILE - VIDEO

The previous two paragraphs discussing the costs per circuit mile for voice and data indicate that the cost for central office facilities plays a dominant role in the overall cost structure. This stems from the need for a large switching plant to derive interexchange voice channel trunking. In the case of video, however, the outside plant costs (i.e., transmission costs) are dominant since the traffic is inherently very wide band with no switching in the voice channel sense. Further, the need for multichannel multiplexing system does not exist.

The 1976 terrestrial video facilities were oriented toward the television broadcast and CATV industries, which are provided with essentially dedicated circuits. Switching is limited to providing the ability to cut-in alternate transmission facilities in the case of failure on the primary lines. This switching cost, when put on a circuit mile basis, is much less than the central office switching costs associated with Direct Distance Dialing (DDD) network.

Video circuit mile costs for 1976 are calculated from FCC data (Ref. 5.1-3). As previously, capital costs are put on an annual basis and added to the annual operating expense to derive total annual video circuit costs.

a. Gross investment in video channels = $237.7 Million

b. Average asset life = 16 Years

c. Annualized capital costs = $14.9 Million

d. Annual operating costs = $41.5 Million

e. Total annual costs = $56.4 Million

f. Video channel miles = 91,588 Miles

g. Annual cost per video channel mile = $616/Mile

The annual operating costs include taxes as required by FCC reporting requirements. The data indicate that the composite average of total annualized costs and channel miles gives an annual cost per video channel mile of 616 dollars.

5.1.6 TRANSMISSION FACILITY COSTS

This section investigates the costs associated with the three types of terrestrial transmission facilities of microwave radio relay, coaxial cable, and fiber optics cable. To permit comparisons to be made on a common basis, it is assumed that each terrestrial transmission mode transmits video traffic. The video service type is selected since it permits a clearer analysis of the transmission costs because central office switching, trunk and line equipment, and multiplex equipment are eliminated.

5.1.6.1 Microwave Radio Relay Costs

Table 5.1-6 gives the cost components in 1976 dollars of a typical microwave radio relay system handling video traffic at distances up to 500 miles. Each microwave route is assumed to consist of six active radio carriers and two standby carriers. Each radio frequency carrier is capable of transmitting one video channel.

5.1.6.2 Coaxial Cable Costs

Table 5.1-7 presents the cost items comprising a coaxial cable system suitable for transmitting video traffic. Costs are presented in 1976 dollars, as was done for the microwave radio relay case. The depreciation schedule for the coaxial cable equipment items is 33 years compared to an average life of 15 years used in calculating the cost of microwave equipment in Table 5.1-6. Six video channels are generally accommodated in a single coaxial cable system permitting the proportionate allocation of cost among each of the six video traffic channels.

Table 5.1-7 indicates that the total cost for a 500 mile coaxial cable system, including the annualized capital cost and the recurring costs, equals $780 per channel mile per year, in 1976 dollars.

TABLE 5.1-6. MICROWAVE RADIO RELAY COSTS FOR VIDEO SERVICE
(Cost in Thousands of 1976 Dollars)

COST ITEM	500 MILES
CAPITAL COSTS	
Radios	5,808
Towers	1,340
Antennas	1,680
Shelters	315
Power	506
Spares	50
Switching & Baseband Equipment	60
Test Equipment	150
Installation	1,100
Eng. & Civil Works	550
Total Capital Cost	11,559
Depreciation, Years	15
Total Capital Cost/Year	771
RECURRING COSTS	
Maintenance	255
Rental Space	9
Real Estate Taxes	50
Rental, Vehicles	20
General & Administrative	200
Depreciation	300
TOTALS	
Total Expenses/Year	834
Total Costs per Year	1,605
No. Video Channel Systems	6
Cost/Channel-Mile/Year	0.535

TABLE 5.1-7. COAXIAL CABLE COSTS FOR VIDEO SERVICE
(Cost in Thousands of 1976 Dollars)

COST ITEM	500 MILES
CAPITAL COSTS	
Ducts	9,484
Cable	13,913
Line Terminals	-
Baseband and Switching Equipment	60
Splices	833
Repeaters	6,283
Total Capital Cost	30,573
Depreciation	33
Annual Capital Cost	927
RECURRING COSTS	
Maintenance and Repair	488
General and Administrative	355
Depreciation	570
TOTALS	
Total Expenses/Year	1,413
No. Video Channel/Systems	6
Cost Channel-Mile/Year	0.78

5.1.6.3 Fiber Optics Cable Costs

Table 5.1-8 summarizes the costs for a fiber optics cable system for the transmission of video traffic comparable to that used as the basis for the cost analysis for the microwave and coaxial cable cases.

The more detailed costing given in Tables 5.1-6 and 5.1-7 for microwave and coaxial cable, respectively, is not provided in the fiber optics case since the system is still in its development stage and most cost elements must be estimated. The primary basis for the cost estimation is ITT internal developments and analyses.

Table 5.1-8 shows that the comparative 500 mile video circuit costs amount to $835 per video channel mile per year.

TABLE 5.1-8. FIBER OPTICS CABLE COSTS FOR VIDEO SERVICES (Costs in Thousands of Dollars)

COST ITEM	500 Miles
CAPITAL COSTS	
Total Capital Cost	14,501
Depreciation	33
Annual Capital Cost	439
Total Expenses/Year	2,067
No. Video Channels/System	6
Cost Channel-Mile/Year	0.835

5.1.6.4 Composite Terrestrial Circuit Costs

The costs for a video circuit given in Tables 5.1-6, -7 and -8 for microwave radio relay, coaxial cable, and fiber optics cable, respectively, are used to derive a composite terrestrial circuit cost. The composite 1976 cost is derived by weighting

each component by the percentage of traffic carried by that component in 1976. The results are shown in Table 5.1-9.

TABLE 5.1-9. COMPOSITE 1976 COST FOR A TERRESTRIAL VIDEO CHANNEL (Based on a 500 Mile Circuit Length)

Media	Annual Cost per Channel Mile ($)	Percent in Use	Weighted Cost per Channel Mile
Microwave	535	67	359
Coaxial Cable	780	33	257
Fiber Optics Cable	835	Neglig.	Negligible
Total Weighted Cost			616

5.1.7 COST PROJECTIONS FOR 1980, 1990 AND 2000

The cost for the terrestrial communication facilities developed in 1976 and 1978 dollars is projected to the benchmark years of 1980, 1990 and 2000 in this paragraph. Cost predictions for the next twenty years are subject to the inaccuracies resulting from technology changes affecting each terrestrial media. Fluctuations in the economy which affect costs have been eliminated from the projections by using constant 1976 dollars for microwave radio relay and coaxial cable and 1978 dollars for fiber optics.

Table 5.1-10 presents the cost projections for all three terrestrial facilities, microwave radio relay, coaxial cable, and fiber optics, divided into annualized capital costs and recurring costs. The cost estimates are based on an average route length of 500 miles for the transmission of a wideband video signal. As explained previously, a video channel is selected for the estimate since it presents a very wide band signal (i.e., 4-6 MHz) and, therefore, is the least complicated in terms of baseband channelization.

A further division is made in the table between analog and digital facilities since it is anticipated that digital facilities will become increasingly more prevalent during the next two decades. Cost comparisons between digital and analog multiplex and transmission equipment will favor the digital variety as LSI technology continues to advance at its current rate. The circuit mile cost for each medium, therefore, is a weighted average of analog and digital facility costs, with the earlier years more heavily weighted toward analog and the later years more heavily toward digital.

An important consideration in projecting the relative mix between analog and digital facilities is the large capital investment in current analog plant. As was noted previously, decommissioning of domestic telecommunications plant is occurring at a rate of three to four percent per year. This inertia, brought about by the enormous plant investment of the domestic telecommunications industry, has a dampening effect on radical changes induced by advances in the technology. The change to digital terrestrial facilities is projected, therefore, as a gradual one.

The second technological consideration highlighted in Table 5.1-10 is the growing importance of fiber optics as a terrestrial communications medium. Fiber optics contributes an insignificant amount to the current domestic telecommunication plant, as shown in the table, but overtakes coaxial cable

TABLE 5.1-10. COMPOSITE TERRESTRIAL VIDEO CIRCUIT COSTS (1976-2000)

YEAR	ITEM	CAPITAL COSTS Analog $	Analog %	Digital $	Digital %	Weighted $	RECURRING COSTS Analog $	Analog %	Digital $	Digital %	Weighted %	Total Costs Weighted $	Percent In Mix %	Total Composite $
1976	Microwave	257	100	N.A.	-	257	278	100	N.A.	-	278	535	67	359
	Coax Cable	309	100	N.A.	-	309	471	100	N.A.	-	471	780	33	257
	F.O. Cable	-	-	-	-	-	-	-	-	-	-	-	-	-
														$\boxed{616}$
1980	Microwave	254	95	200	5	251	275	95	220	5	272	523	67	350
	Coax Cable	309	100	N.A.	-	309	453	100	N.A.	-	453	768	33	253
	F.O. Cable	160	70	130	30	150	566	70	639	30	588	738	-	0
														$\boxed{603}$
1990	Microwave	250	50	190	50	220	264	50	210	50	237	457	55	251
	Coax Cable	300	50	234	50	267	430	50	453	50	442	709	20	142
	F.O. Cable	60	40	34	60	50	344	40	370	60	360	410	25	103
														$\boxed{496}$
2000	Microwave	245	40	200	60	219	264	40	216	60	236	455	50	228
	Coax Cable	290	10	222	90	228	429	90	450	10	432	660	5	33
	F.O. Cable	55	10	40	90	42	340	10	362	90	360	402	45	181
														$\boxed{442}$

Notes:
1. Costs are in constant 1976 dollars per video channel mile.
2. Cost estimates based on 500 mile circuit length.
3. Microwave in 1990: 30% AR6A, 20% conventional FDM/FM, 50% digital.
   Microwave in 2000: 40% AR6A, 60% digital.

an insignificant amount to the current domestic telecommunication plant, as shown in the table, but overtakes coaxial cable by 1990 with a 25 percent share in the mix. By the year 2000, fiber optics is predicted to provide nearly as much of the video terrestrial plant as microwave radio relay. This will largely be at the expense of coaxial cable.

The extreme right-hand column of Table 5.1-10 gives the total composite average video circuit mile costs for the years 1976, 1980, 1990 and 2000. A decreasing cost per video circuit mile is indicated. The 1976 composite cost is $616 per video circuit mile, which decreases to $442 per video circuit mile in 2000. The cost estimates are based on a 500 mile circuit length. The cost trend for each terrestrial medium as well as the composite is shown graphically in Figure 5.1-1.

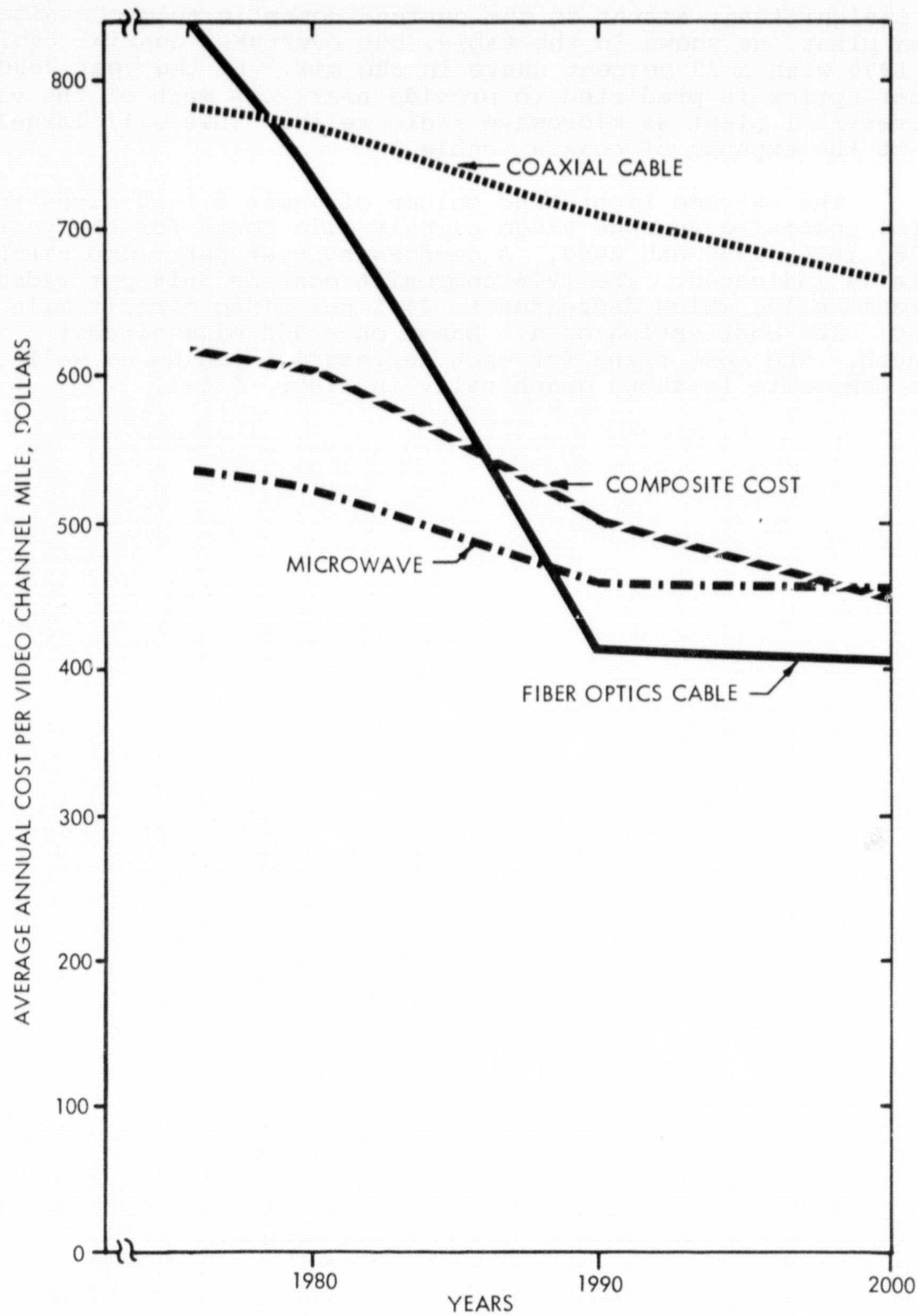


FIGURE 5.1-1. ANNUAL TERRESTRIAL VIDEO CIRCUIT COSTS
(Constant 1976 Dollars)

5.2 TERRESTRIAL COMMUNICATIONS COST - SHORT HAUL

Short haul terrestrial communications links will be needed to support local distribution of satellite trunking earth stations as well as to provide interconnection between two space diversity earth station sites which are employed for reliability purposes. Links between the earth station and central switching offices or distribution points are sometimes referred to as terrestrial "tails." The average distance of these terrestrial tails is estimated to be 50 miles.

The distances between diversity earth stations are anticipated to be less than the average given above for the terrestrial tails connecting to local facilities. Spacing between diversity sites may be as little as five to seven miles. As a result, the projections for cost per mile are given in four to five increments of mileage, up to 50 miles.

As in the previous subsection on long haul terrestrial facilities, circuit mile costs are based on the transmission of a video channel since this represents the least complicated transmission costing option. Also, costs are given in constant 1976 dollars to avoid entangling the analysis with monetary projections.

5.2.1 ASSUMPTIONS

The general assumptions concerning terrestrial communications facilities given in paragraph 5.1.1 are applicable here since the same type of equipment is used, but for shorter distances. The following additional assumptions are also used in the analysis.

a) Tails may be of lengths from several miles to over 100 miles, but are assumed in this study to be 50 miles in length, an acceptable average in view of current history of earth station locations.

b) Traffic through tails is destined only for satellite transmission.

c) Constant dollars, basis, 1976, are used in the cost analyses.

d) Transmission facilities include microwave, coaxial cable, and fiber optics cable systems.

5.2.2 COST METHODOLOGY

The cost methodology explained in paragraph 5.1.2 is applicable to the pricing of short haul transmission systems as well as long haul. The same depreciation used in paragraph 5.1.2 is used here.

While cost comparisons are made between microwave radio relay, coaxial cable, and fiber optics cable, the first medium is the most applicable for use as terrestrial tails, since radio is the easiest medium to implement where right-of-way access is difficult. In most cases, the "tails" are located in densely populated areas in comparison to the long haul segments.

5.2.3 BASELINE COSTS

Costs for the terrestrial tails are first derived for the baseline year of 1976 in order to project costs to the future years of 1980, 1990, and 2000. Cost comparisons are made between microwave radio relay, coaxial cable, and fiber optics cables. As previously noted, fiber optics costs are based on data from the year 1978 since this data is more significant to the analysis than 1976.

The transmission media are priced for circuit distances of one to fifty miles including both capital and recurring charges. All facilities are assumed to begin their depreciation life in 1976 with no prior depreciation reserves on assets. Straight line depreciation is used on the basis of the average mix of equipment needed for each type of medium. The depreciation life of the combined assets for a microwave radio relay system is 15 years, and for coaxial cable and fiber optics cable the combined depreciation life used is 33 years. The cost for land is excluded from the analysis since it is non-depreciable and its cost is assumed to be fully recoverable upon liquidation.

5.2.3.1 Microwave Radio Relay Costs

Table 5.2-1 presents microwave radio relay capital and recurring costs for a transmission path handling video bandwidths for short haul distances of one to fifty miles. The cost items in the top half of the table give the major capital items which are put on an annual cost basis by dividing the total cost by the yearly straight line depreciation rate.

Recurring costs are included in the second half of the table. The two most significant items in this category are maintenance and general and administrative expenses, which account for approximately 70 percent of the total recurring costs.

Similar to the long haul microwave path priced in paragraph 5.1.6.1, the short haul route is assumed to be composed of six active radio frequency systems and two standby systems. As a result, the capital and recurring costs are divided equally among the six active video channels since each is assumed to occupy a full radio carrier. A fifty mile microwave radio tail, therefore, is estimated to cost $1,057 per video channel mile per year in 1976 dollars.

TABLE 5.2-1. MICROWAVE RADIO RELAY COSTS FOR TERRESTRIAL TAILS
(Cost in Thousands of 19[illegible] Dollars)

VIDEO SERVICE

COST ITEM	1 Mile	10 Mi.	25 Mi.	50 Mi.
CAPITAL COSTS				
Radios	528	528	528	792
Towers	140	140	140	200
Antennas	80	80	80	160
Shelters	15	15	15	30
Power	46	46	46	69
Spares	3	3	3	5
Switching & Baseband Eq.	60	60	60	60
Test Equipment	40	40	40	50
Installation	100	100	100	150
Eng. & Civil Works	50	50	50	75
Total Capital Cost	1,062	1062	1062	1591
Depreciation, Years	15	15	15	15
Total Capital Cost/Yr.	71	71	71	106
RECURRING COSTS				
Maintenance	60	60	60	80
Rental Space	9	9	9	9
Real Estate Taxes	2	2	2	3
Rental, Vehicles	4	4	4	4
General & Adminis.	50	50	50	75
Depreciation	30	30	30	40
TOTALS				
Total Expenses/Year	155	155	155	211
Total Costs per Year	226	226	226	317
No. Video Channel Sys.	6	6	6	6
Cost/Chan.-Mile/Year*	37,700	3767	1507	1057

*Cost in Dollars

5.2.3.2 Coaxial Cable Costs

Capital and recurring costs attributable to a terrestrial tail implemented with a coaxial cable system are given in Table 5.2-2. Pricing is estimated in 1976 dollars for route lengths of 1, 10, 20, 30 and 50 miles, and are based on the transmission of video signals as in the previous paragraph.

The coaxial cable and the cable ducts are the highest cost components. Repeaters, however, are a significant cost component at the longer path lengths. As indicated in paragraph 5.1.6.2, the composite average depreciation for a coaxial cable system servicing video is 33 years, which is considerably higher than the 15 years used for the microwave system. Recurring costs are based on 1976 experience for maintenance and repair, general and administrative, and depreciation expenses, and are nearly three times higher than the annualized capital cost for route lengths approaching 50 miles. This is the result of the long depreciable life of the coaxial cable system.

The coaxial cable tail is assumed to carry six active video channels as does the microwave radio system. In deriving video channel mile costs, therefore, the total cost is divided among the six video channels. Table 5.2-2 indicates that the cost estimation for a 50 mile coaxial cable tail is $1,143 per video circuit mile per year in 1976 dollars. This figure is slightly higher than the microwave radio system for the same route length.

5.2.3.3 Fiber Optics Cable Costs

Table 5.2-3 presents summary results for the fiber optics cable costs. Good historical cost data is not available for fiber optics cable since it is a newly emerging technology with very little in-place plant in comparison to microwave radio and coaxial cable.

The cost elements used in the analysis are similar to the coaxial cable case, and an identical pricing method is used to determine short haul circuit mile costs. As with the more traditional terrestrial media, the recurring costs are the dominant cost factor.

A 50-mile terrestrial tail implemented with a fiber optics cable costs $1,676 per video circuit mile per year. This cost is somewhat higher than the corresponding cost for conventional terrestrial media but, as will be seen in the following section, fiber optic costs are decreasing more rapidly than the corresponding costs for microwave and coaxial cable.

TABLE 5.2-2. COAXIAL CABLE COSTS FOR TERRESTRIAL TAIL
(Cost in Thousands of 1976 Dollars)

VIDEO SERVICE

COST ITEM	1 Mile	10 Miles	20 Miles	30 Miles	50 Miles
CAPITAL COSTS					
Ducts	19.0	189.7	379.4	569.1	948.4
Cable	27.8	278.2	556.5	834.8	1,391.3
Line Terminals	-	-	-	-	-
Baseband & Switching Equip.	60.0	60.0	60.0	60.0	60.0
Splices	1.9	16.7	33.4	50.2	83.4
Repeaters	-	128.5	257.0	385.6	628.3
TOTAL CAPITAL COST	108.7	673.1	286.4	1,899.6	3,111.4
DEPRECIATION	33.0	33.0	33.0	33.0	33.0
ANNUAL CAPITAL COST	3.0	20.0	39.0	58.0	94.0
RECURRING COSTS					
Maintenance & Repair	7.0	40.0	68.0	88.0	105.0
General & Administrative	5.0	28.0	50.0	67.0	87.0
Depreciation	2.1	12.2	23.4	34.6	56.6
TOTALS					
Total Expenses/Yr.	14.1	80.0	141.5	190.0	249.0
No. Video Chan/Sys.	6.0	6.0	6.0	6.0	6.0
Cost/Channel-Mile/Yr.*	2,833.0	1,667.0	1,500.0	1,378.0	1,143.0

*Cost in dollars

TABLE 5.2-3. FIBER OPTICS CABLE COSTS FOR TERRESTRIAL TAILS
(Costs in Thousands of 1976 Dollars)

VIDEO SERVICE

COST ITEM	1 Mi.	10 Mi.	20 Mi.	30 Mi.	50 Mi.
CAPITAL COSTS					
Total Capital Cost	127	390	678	966	1561
Depreciation	33	33	33	33	33
Annual Capital Cost	4	12	21	29	47
Total Expenses/Year	28	151	265	354	455
No. Video Channel/System	6	6	6	6	6
Cost/Channel Mile/Year*	5275	2709	2382	2127	1676

*Cost in Dollars

5.2.4 COST PROJECTIONS FOR 1980, 1990, AND 2000

The impact of technology will result in cost reductions for all media, but with substantial cost lowering of fiber optics cable. Frequency allocations for new microwave radio systems are becoming scarce in densely populated areas with the result that enhancement of channel capacity within existing systems has become an important objective. For example, the Bell System's AR6A amplitude modulated single-sideband suppressed carrier radio provides a three to one improvement in the number of voice circuits transmitted in comparison to standard microwave frequency modulated radios. In addition, improvements can be expected in compression and modulation techniques resulting in higher data rates per cycle of bandwidth.

The significant trend affecting terrestrial media costs during the next two decades will be the increased circuit capacity of the microwave radio, coaxial cable, and fiber optics media. This will result in an effective reduction in capital and recurring costs when put on a per channel basis. The per channel cost reduction will be applicable to voice, video, and data services but will be more pronounced in the video area since the cost of voice channel multiplexing is absent. The use of digital multiplexers, however, will help lower the cost of voice and data services as large scale integration (LSI) continues to lower the equipment costs and improve system reliability and, thereby, lower maintenance costs.

Table 5.2-4 presents the cost projections for the terrestrial tails media for the years 1980, 1990, and 2000. The baseline year of 1976 is also shown on the table. The cost projections show the anticipated mix of analog and digital facilities estimated for each media as a function of year. For the reasons given above, it is estimated that digital facilities will be cheaper than the corresponding analog facilities for each media. The inertia of the existing plant investment dictates that the analog facilities will be predominant during the earlier years but the mix will favor the digital facilities in the latter years when the cost advantage of digital equipment begins to make an impact on plant investment. This is especially true for the new medium of fiber optics. The table shows that in the year 2000 the mix is 10 percent analog and 90 percent digital for this medium.

The overall cost reductions anticipated for microwave radio and coaxial cable is rather modest. The cost of a microwave terrestrial tail is estimated to decrease from $1057 per video circuit mile per year in 1976 to $894 per video circuit mile per year in 2000. Similarly, the coaxial cable video circuit mile

TABLE 5.2-4. TERRESTRIAL TAIL COST PROJECTIONS (1976-2000)

50 MILE LENGTH - VIDEO SERVICE

YEAR	ITEM	CAPITAL COSTS					RECURRING COSTS					TOTAL COSTS WEIGHTED
		Analog		Digital		Weighted	Analog		Digital		Weighted	
		$	%	$	%	$	$	%	$	%	$	
1976	Microwave	354	100	-	-	354	703	100	-	-	703	1057
	Coax Cable	313	100	-	-	313	830	100	-	-	830	1143
	F.O. Cable	-	-	-	-	-	-	-	-	-	-	--
1980	Microwave	350	95	276	5	346	695	95	556	5	688	1034
	Coax Cable	313	100	-	-	313	798	100	-	-	798	1111
	F.O. Cable	171	70	139	30	161	1247	70	1408	30	1295	1456
1990	Microwave	344	50	262	50	303	668	50	530	50	599	902
	Coax Cable	304	50	237	50	271	758	50	799	50	799	1050
	F.O. Cable	73	40	41	60	54	759	40	816	60	793	847
2000	Microwave	337	40	276	60	300	668	40	545	60	594	894
	Coax Cable	294	10	225	90	232	756	10	794	90	790	1022
	F.O. Cable	59	10	43	90	45	750	10	798	90	793	838

Notes:
1. Costs are in constant 1976 dollars per video channel mile.
2. Cost estimates based on 500 mile circuit length.
3. Microwave in 1990: 30% AR6A, 20% conventional FDM/FM, 50% digital.
   Microwave in 2000: 40% AR6A, 60% digital.

cost per year is anticipated to decrease from $1143 in 1976 to $1022 in 2000. The coaxial cable decrease is somewhat less than that anticipated for microwave radio.

The more significant cost reduction is that anticipated for fiber optics cable. Table 5.2-3 shows that the cost for transmission of a video channel on a fiber optics 50-mile terrestrial tail is $1676 per circuit mile per year, which is projected to decrease to $838 in the year 2000. This represents a 50 percent cost reduction for fiber optics compared with a 10 percent reduction for coaxial cable for this period.

5.3 CAPACITY OF C AND KU BAND SATELLITES

This subsection estimates the capacity of C and Ku band satellites for supporting communications within the Continental United States (CONUS). Three orbital configurations for synchronous satellites are considered in determining the maximum number of transponders that can be provided by these two frequency bands. The lowest capacity configuration assumes the use of a 4.5 degree orbital spacing, and the highest capacity configuration requires a 3 degree orbital spacing. The intermediate configuration assumes a 4 degree spacing. The calculation of applicable orbital slots for CONUS is based on use of the 70 degree equatorial arc from 65 to 135 degrees west longitude and the minimum look angle of the earth station antennas.

5.3.1 C BAND SATELLITE CAPACITY

The C band satellite capacities given in Figure 5.3-1 show the maximum number of CONUS suitable satellites provided

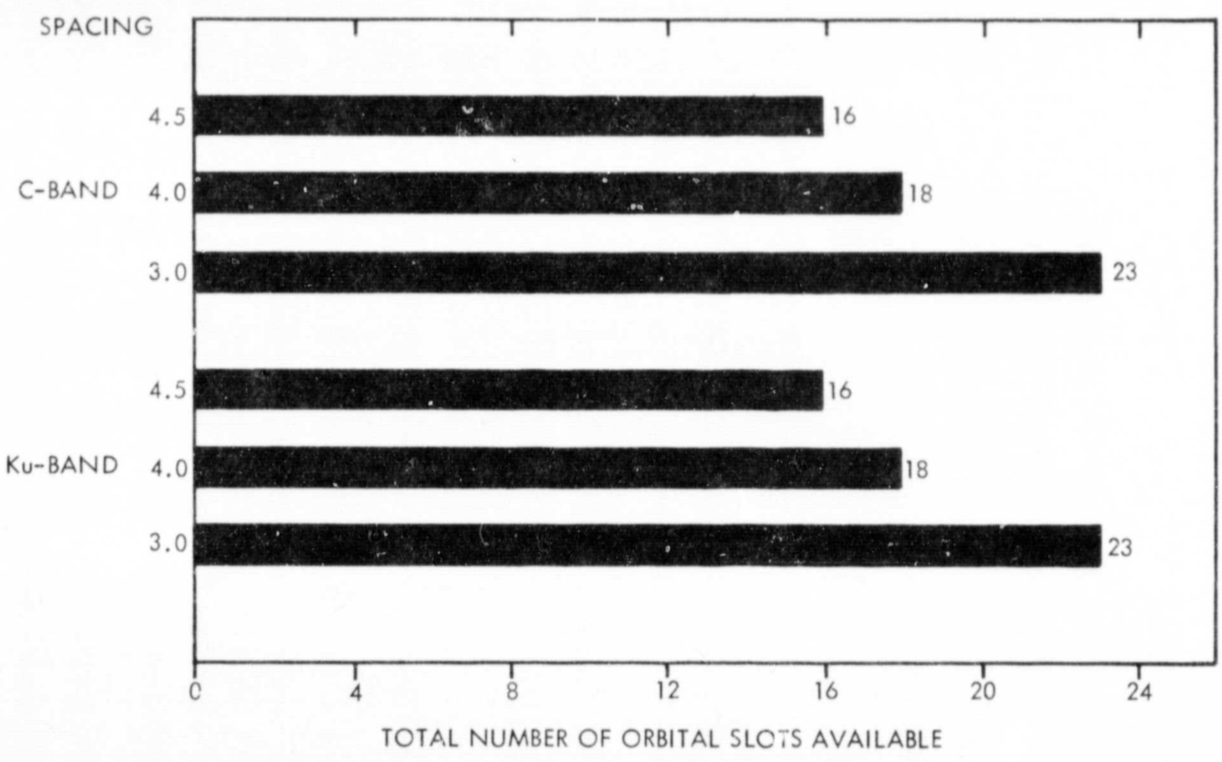


FIGURE 5.3-1. C AND KU BAND ORBITAL CAPACITY

by assuming orbital spacings of 4.5, 4 and 3 degrees. Not all of the possible satellite slots, however, are usable by United States carriers. Accordingly, the capacity estimates provided in this section assume that seven satellite slots are used by other Western Hemisphere countries with the result that the maximum number of slots assignable to U.S. carriers are 9, 11, and 16, respectively. Because of the interference limitations of the lower frequency C band, it does not appear that 3 degree spacings will be permitted for this band. As a result, it is concluded that the maximum orbital capacity for C band synchronous satellites for domestic use will most likely be eleven.

5.3.2 KU BAND SATELLITE CAPACITY

Figure 5.3-1 shows maximum orbital capacity for CONUS domestic satellites in the Ku band. The figure shows the same 4.5, 4 and 3 degree capacities shown for the C band satellites. In this case, however, three degree spacing is possible, permitting as many as 23 satellite slots. Allocation of seven satellite slots for use by other Western Hemisphere nations results in a maximum capacity of 16 satellite slots for use by domestic carriers. The three degree spacing is not currently permitted due to interference problems, but the higher carrier frequency of Ku band and the projected improvements in antenna design make this narrower spacing feasible. The use of three degree orbital spacing, however, will require international approval, possibly at the World Administrative Radio Conference (WARC) to be held this year.

5.3.3 EXISTING AND PLANNED SATELLITES

Figure 5.3-2 shows C and Ku band domestic communication satellites existing and planned excluding those dedicated to military applications. The figure indicates that currently seven C band satellites are in service providing a total of 144 transponders with a 36 MHz bandwidth. All but the two WESTAR satellites have 24 transponders per satellite. WESTAR I and WESTAR II have 12 transponders each.

At present, there are no domestic commercial Ku band satellites in operation. However, among the seven satellites planned for launching during the next few years, five will have Ku band transponders. The planned satellites will add a total of 60 C band and 38 Ku band transponders.

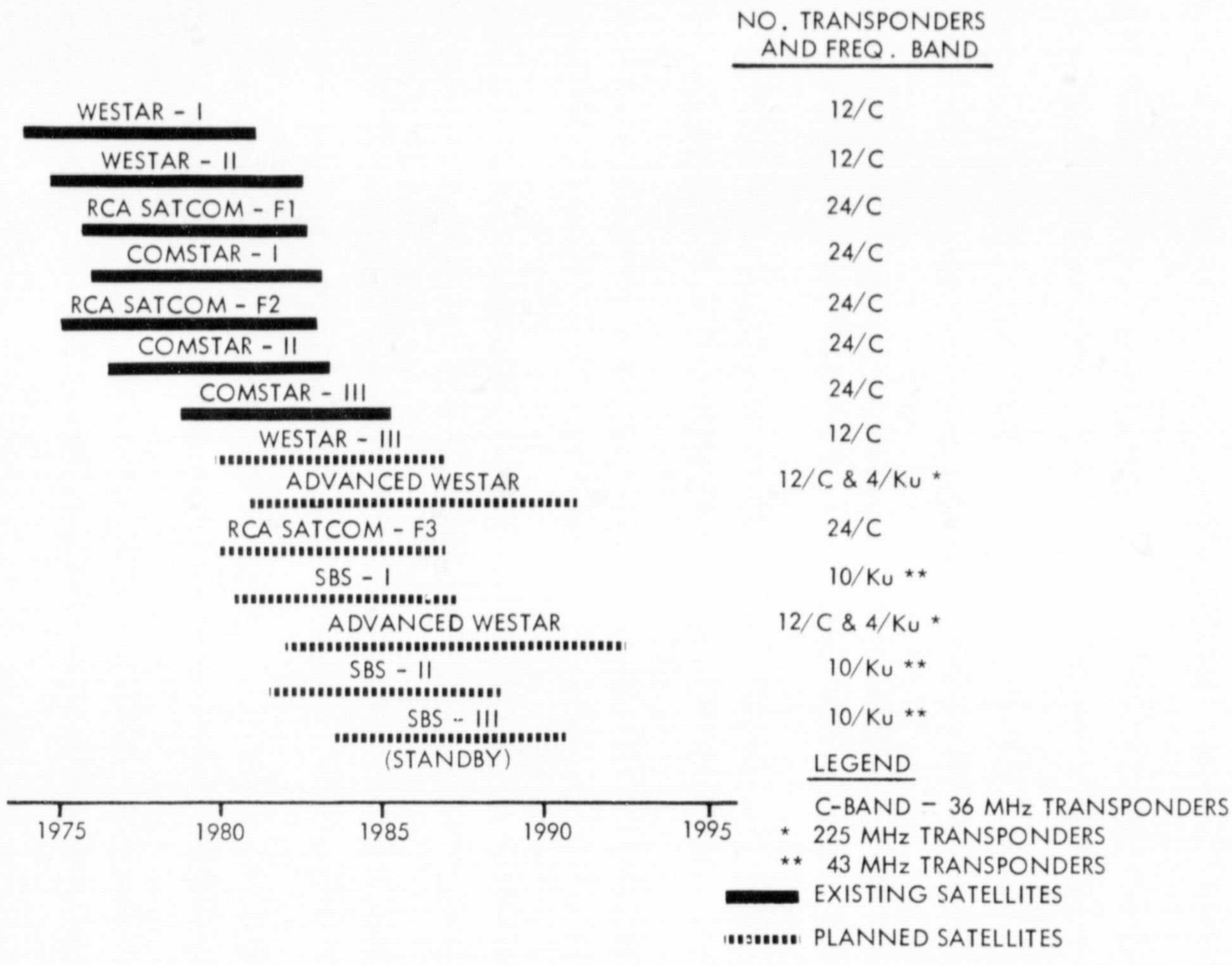


FIGURE 5.3-2. EXISTING AND PLANNED C AND KU BAND SATELLITES

5.3.4 SUMMARY OF TRANSPONDER CAPACITY

Table 5.3-1 summarizes satellite communication capacity in terms of the maximum number of transponders that can be supported by C and Ku band satellites considering the three orbital configurations of 4.5, 4 and 3 degree slot spacings. A capacity of 24 transponders per satellite is used uniformly to determine the cumulative transponder number presented. The columns marked "Total" give the total capacity of the seventy degree orbital arc from 65 to 135 degrees west longitude, and the columns marked "U.S." give the cumulative number of transponders based on the satellite slots deemed assignable to domestic carriers. In each band, seven slots of the total are allocated for use by other Western Hemisphere nations.

TABLE 5.3-1. TRANSPONDER CAPACITY FOR ORBITAL SPACING

Spacing	C Band		Ku Band		C and Ku Band	
	Total	U.S.	Total	U.S.	Total	U.S.
4.5°	384	216	384	216	768	432
4.0°	432	264	432	264	864	528
3.0°	552	384	552	384	1104	768

Figure 5.3-3 presents, in graphical form, the saturation limits estimated for the domestic C and Ku band. The values shown to the left of the vertical line at 1981 indicate the absence of Ku band satellites prior to that year and, therefore, saturation of only C band transponders is indicated. For the years subsequent to 1981, both C and Ku band satellite saturation limits are considered. Based on estimates of the technology and, more important, regulatory actions stemming from international agreements, Table 5.3-2 summarizes the most probable transponder capacity anticipated for domestic use of these two bands.

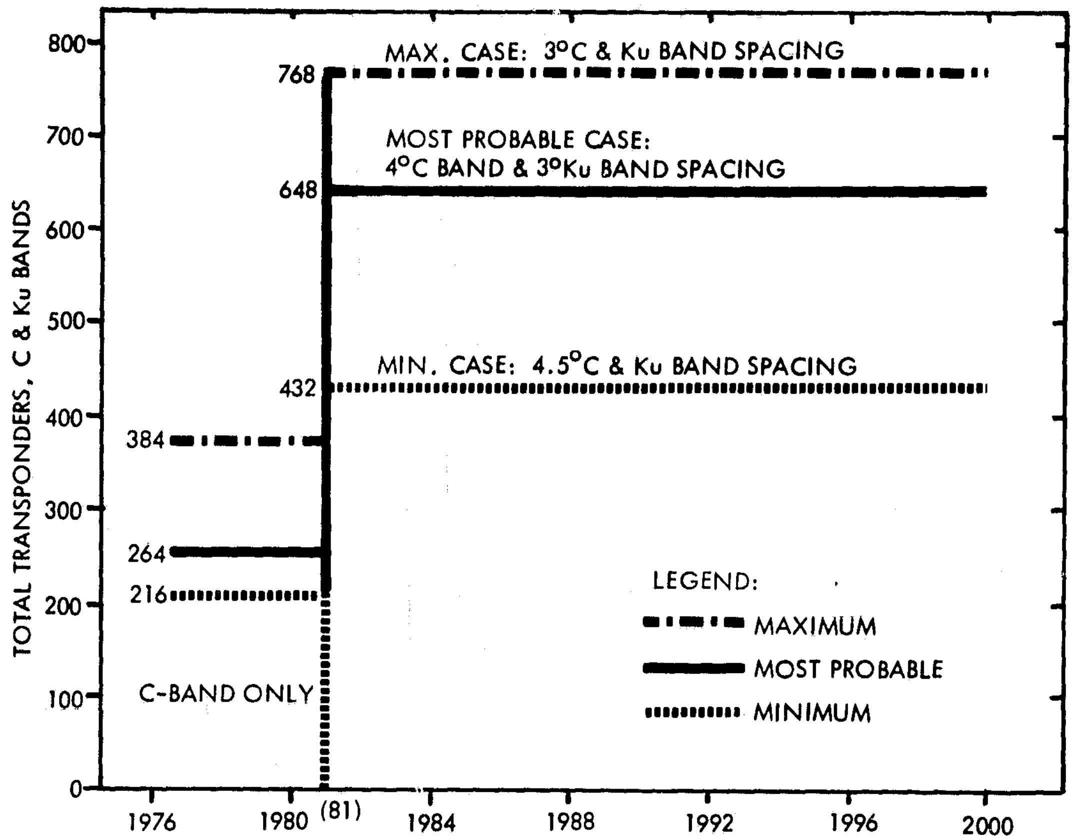


FIGURE 5.3-3. SATURATION LIMITS OF DOMESTIC C AND KU BAND SATELLITES

TABLE 5.3-2. MOST PROBABLE C AND KU BAND MAXIMUM TRANSPONDER CAPACITY

Satellite	Spacing	Total	U. S.
C Band	4°	432	264
Ku Band	3°	552	384
Total		984	648

6.0 DEMAND FOR SATELLITE COMMUNICATIONS

This section forecasts demand for satellite communications through the year 2000.

An evaluation is made of the acceptability of various levels of reliability for each of the communications categories introduced in this study. This leads to an assessment of the overall impact of communications reliability on demand. The assessment is carried out over the range of reliability performance that may be expected for the 30/20 GHz satellites of particular interest in this study.

The degree to which real time requirements (as compared to deferred modes of transmission) influence demand for satellite channels is also investigated.

Finally, demand estimates made in earlier sections are translated into requirements for satellite transponders by considering the effects of peak hour demands, the amount of traffic likely to be captured by satellite systems, and the transmission capacity expected for advanced satellite systems. The forecast demand for satellite transponders is compared with the capacity projected for C and Ku band systems to arrive at an estimate of when C and Ku capacity will become saturated.

6.1 SERVICE DEMAND AS A FUNCTION OF RELIABILITY

Transmission in the 30/20 GHz band is subject to occasional disruption due to heavy rainfall. Satellite communications at these frequencies is therefore at a disadvantage with respect to applications having stringent reliability requirements. The following discussion assesses those services that are acceptable at various levels of reliability and estimates the total demand for them for the years 1980, 1990, and 2000.

6.1.1 CHARACTERIZATION OF 30/20 GHz SATELLITE RELIABILITY

The most appropriate single measure of reliability for evaluating communications performance under the present task is "Availability". This measure expresses the percentage of time for which acceptable levels of performance are achieved. In this report, availability levels of 99.99 percent, 99.9 percent, 99.5 percent, and 99.0 percent are considered as potential design goals, and the degree of user acceptance at each level is estimated.

A specified availability value, however, is not in itself sufficient to allow the evaluation of the acceptability of a communications link. Availability relates only to the aggregate hours of outage and does not indicate how the individual outages are distributed. For example, an availability of 99.9 percent indicates that a communications link will be operable for 99.9 percent of the hours in a year (i.e., 0.999 x 8760 hrs/yr = 8751 hrs.). A link having this availability will therefore have outages totaling 8760 - 8751 = 9 hours per year. Without additional information, however, there is no indication of whether a single nine-hour outage is typical of the link or whether many short outages are involved. Since most communications applications are sensitive to the durations of the individual outages, as well as the aggregate of all outages, additional information, as discussed below, is needed to more fully characterize the link before rational evaluations can be made.

The statistics of rainstorms throughout the United States have been thoroughly reported and many studies exist which model the performance of communications links in terms of these statistics (Ref. 6.1-1). However, other than aggregate value, there is very little data available on the durations of rainfall at or above given intensity levels, so that these models fall short of providing the more detailed outage distributions desired. Nevertheless, reasonable estimates based on the observed duration of thunderstorms (which are responsible for most of the high intensity rainfall) are possible. Table 6.1-1 characterizes the reliability performance of 30/20 GHz satellite links in terms of availability, aggregate outages, and typical outage frequency and duration. All of these factors depend on the design of the link, the geographical areas covered, the quality of communications desired, and many other variables. This table therefore provides only broad guidance as to typical link performance that may be expected. Actual performance may vary considerably from these estimates, but the values shown are considered a reasonable description for purposes of evaluating the acceptability of these links for various communications applications.

TABLE 6.1-1. TYPICAL RELIABILITY PERFORMANCE

Availability (Percent)	99.99	99.9	99.5	99.0
Aggregate Outage (Hours per Year)	0.9	9	44	88
Typical Frequency (Outages per Year)	11	35	105	175
Typical Duration (Minutes)	5	15	25	30

The higher levels of reliability shown in Table 6.1-1 correspond to link designs that include relatively large fade margins and/or the use of two or more earth stations to provide space diversity. The lower levels are characteristic of links designed with lesser fade margins and without diversity. Outages associated with the higher reliabilities are less frequent and of shorter duration since links designed to a higher availability criteria will less often encounter rain intensities beyond the links' capability for penetration. Outages typical of links designed for lower levels of availability are both more frequent and of longer duration.

Outage frequency vs outage durations corresponding to each of the availability levels discussed in Table 6.1-1 are shown graphically in Figure 6.1-1. The values postulated for typical 30/20 GHz satellites are plotted on the same scale. For comparison purposes, an average availability of 99.8 percent typical of present day leased line service (Ref. 6.1-2) is shown as a dashed line. This value is also consistent with estimates for the switched telephone network. For example, a Bell System Technical Reference (Ref. 6.1-3) defines interval reliability as the probability that a call of 10-minute duration can be completed without being erroneously disconnected by switched network equipment, and states that interval reliability for the switched network exceeds 0.998. Statistics for the ARPANET showed an availability of 99.62 percent during the first eight months of 1974, and this is indicated to be a considerable improvement over results obtained in earlier years (Ref. 6.1-4).

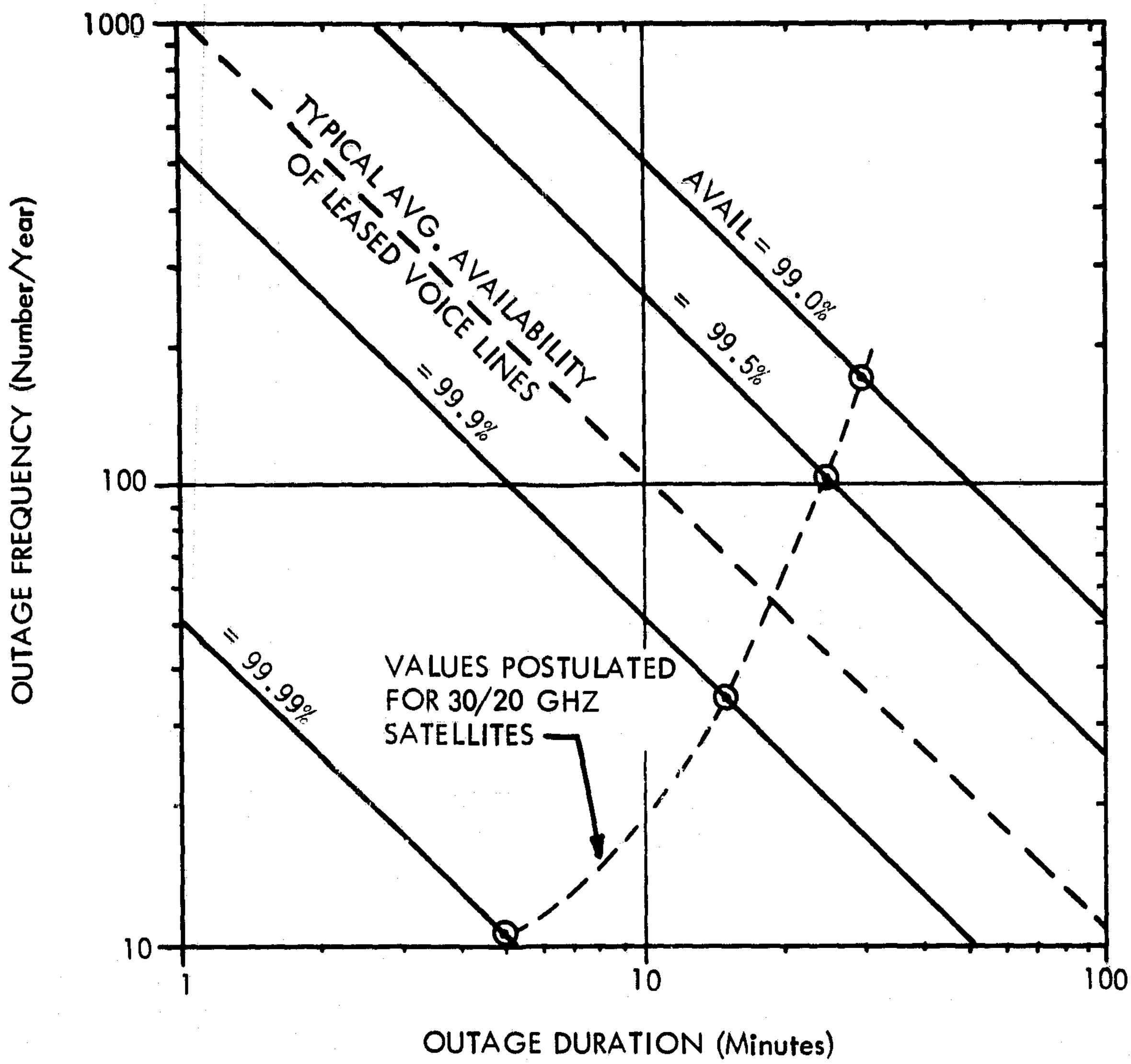


FIGURE 6.1-1. FREQUENCY AND DURATION OF OUTAGES

Based on the typical performance levels discussed above, a value of 99.9 percent availability may be characterized as roughly equivalent to or slightly better than most of today's telecommunications services, while 99.99 percent is considerably better and values of 99.5 and 99.0 percent are substantially poorer than those currently provided.

6.1.2 METHODOLOGY FOR ESTIMATING DEMAND VS AVAILABILITY

The degree of user acceptance of a communications service offering a given level of availability varies widely from user to user, and from application to application. In the common user environment anticipated for 30/20 GHz satellite service, a large number of diverse user requirements are represented. As a consequence, user acceptance corresponding to various levels of performance necessarily refers to broad average values appropriate to loosely defined communities of users. Because of this diversity, the most practical way of estimating the degree of user acceptance is to consider each category of service in turn, and to assign values based on informed estimates of the criticality of the types of applications that are likely to make use of that category.

In the analysis that follows, the characterization of 30/20 GHz satellite reliability arrived at in Section 6.1.1 was used as a guidepost. For example, since an availability of 99.99 percent represents a level of performance above that commonly encountered on most other communications media, it is assumed in the analysis that, unless special requirements so dictate, no special user motivation is necessary to make such service fully competitive with other modes. In this case a relative weighting of 100 percent was assigned to reflect the competitive rating of the satellite link relative to other modes.

There are, however, some communications applications for which even the high level of availability represented by 99.99 percent is not considered suitable. Most notably, this occurs in the case of network TV and, to a lesser extent, for CATV and for some CPU-to-CPU traffic. Many users in these critical groups are accustomed to, and demand, exceptionally high levels of reliability (typically provided by allocating redundant paths via special terrestrial circuits). The degree of acceptance by these users of a 30/20 GHz satellite link, even at 99.99 percent availability, is therefore somewhat diminished, and this is reflected by assigning a competitive rating value less than 100 percent for these categories of traffic. This implies that some additional motivation must be supplied to these user classes before they will accept 30/20 GHz satellite service at 99.99 percent availability on a basis fully competitive with other communications options open to them. The predominant method of providing such motivation is a reduction in costs.

To explore the trade-off between availability and cost, the degree of acceptability for each communications application was additionally estimated under the assumption that a substantial cost advantage (20 to 30 percent) could be offered to motivate

selection of the 30/20 GHz satellite link. Naturally, an application for which the satellite link was considered to be fully acceptable (i.e., a link assigned a competitive level of 100 percent without additional cost motivation) would also receive a rating of 100 percent when the added inducement of cost reduction is included. But an application in which, for example, only 20 percent competitive acceptability was initially allocated might have this acceptance level increased to perhaps 40 percent if substantial cost benefit is offered. Such estimates were made for each of the components of traffic demand.

A similar procedure was followed for levels of availability of 99.9 percent, 99.5 percent, and 99.0 percent. Acceptability for each application was evaluated first under the assumption that 30/20 GHz satellite costs are equivalent to those of alternative communications modes, and then with the assumption that a substantial cost advantage can be provided.

It should be noted that the acceptance percentages discussed above do not refer to the amount of traffic that may be captured by 30/20 GHz satellites. The acceptance percentage refers only to that fraction of traffic demand for which the stated level of availability performance would be adequate. The amount of traffic actually captured involves other considerations as well and is treated elsewhere. Similarly, the acceptance percentage in defining a fraction of communications demand does not pertain directly to satellite sizing. The latter involves additional considerations of grade-of-service and traffic peaking which are not reflected in the acceptability figures developed here.

The procedure described below summarizes the preceding discussion and provides a step-by-step overview of the methodology used. These steps were followed in developing the tables of demand vs availability presented in the following sections of this report.

1. Estimate the percentage of traffic in each service category for which each level of availability is acceptable using the channel reliability performance described in Table 6.1-1 as a guide.

    a) At a cost comparable to other communications modes existing in the same time frame.

    b) At a cost substantially lower than other communications modes existing in the same time frame.

Comment:

Each component was separately estimated by several investigators familiar with communications technology and the types of applications likely to be of concern to the user community. The estimates were then jointly compared and an overall consensus arrived at for the percentage of traffic in each category for which each level of availability is likely to prove acceptable.

2. Obtain total traffic estimates for each of the components making up voice, video and data traffic demand as developed in Section 2.4 of this report.

   Comment:

   The traffic components included are those involving distances of 200 miles or more. Base line traffic without peaking factors is used to express demand in terms of overall traffic volume rather than peak hour traffic intensity.

3. Multiply the percentage estimated in step 1 for each traffic component by the corresponding traffic volume to obtain the traffic volume of each type for which each level of availability is acceptable.

4. Sum the components of voice, video and data traffic services, respectively, to form estimates of the total demand for each service for which each level of availability is acceptable. Compare with total voice, video, and data traffic referred to in step 2 to arrive at percentages of the total voice, video and data traffic for which each level of availability is acceptable.

6.1.3 ANALYSIS OF SATELLITE DEMAND VS AVAILABILITY

The methodology described in the preceding section is used here to analyze satellite demand vs availability. Tables 6.1-2, 6.1-3, and 6.1-4 present the acceptability percentage allocated for each of the traffic components included respectively in the voice, video and data traffic projections. Since the degree of acceptability assigned for each level of availability is relatively independent of the year, a single chart for each service was found to be adequate.

Voice traffic is generally tolerant of channel outages at availability levels at or above the performance typical of today's communications alternatives. Furthermore, users of dial-up services can, without too much disruption, re-dial a failed call and, in most cases, will find an alternate route through terrestrial links. Consequently, as shown in Table 6.1-2, 100 percent acceptance has been assigned for MTS and WATS traffic at both the 99.99 percent and 99.9 percent availability levels, whether or not a cost inducement is offered. Private line users, however, must go to additional trouble and expense to achieve a dial backup capability, and there is therefore a higher motivation for those private line users with stringent reliability requirements, to prefer more reliable modes of communications. This is reflected by assigning 90 percent acceptability to the private line users for communications availability at the 99.9 percent level. With a substantial cost inducement, however, it is likely that service at the 99.9 percent level would be acceptable to these more critical users, and thus to virtually all voice users, as reflected in the 100 percent acceptability values assigned in the appropriate columns of Table 6.1-2.

When performance at the substantially poorer reliability levels represented in the 99.5 percent and 99.0 percent columns is considered, the acceptability factor for the voice traffic components falls off considerably. Very few voice users are considered willing to tolerate a telephone system with half-hour outages occurring every few days, as would be the case at these lower availabilities. User rejection of service at these lower availability levels may be expected to be reinforced by the existence of alternative communications modes with better performance and by the high quality of service that the public has grown to expect from the existing telephone plant. Thus, the acceptability percentages assigned for the lower performance channels in Table 6.1-2 are low and, as indicated in the Table, even a substantial cost inducement is not considered likely to raise the acceptability to respectable levels.

TABLE 6.1-2. VOICE TRAFFIC DEMAND
PERCENT ACCEPTABLE VS AVAILABILITY

SERVICE	99.99%		99.9%		99.5%		99.0%	
	SAME COST	LESS COST	SAME COST	LESS COST	SAME COST	LESS COST	SAME COST	LESS COST
MTS RESIDENTIAL	100	100	100	100	10	20	0	0
MTS BUSINESS	100	100	100	100	10	20	0	0
WATS	100	100	100	100	10	30	0	10
PRIVATE LINE	100	100	90	100	0	20	0	10

TABLE 6.1-3. VIDEO TRAFFIC DEMAND
PERCENT ACCEPTABLE VS AVAILABILITY

SERVICE	99.99%		99.9%		99.5%		99.0%	
	SAME COST	LESS COST	SAME COST	LESS COST	SAME COST	LESS COST	SAME COST	LESS COST
NETWORK TV	20	40	10	30	0	0	0	0
CATV	90	100	30	50	0	10	0	0
VIDEO-CONF.	100	100	70	80	0	10	0	0
EDUCATION	100	100	70	80	10	30	0	0
HEALTH & PUB. AFF.	100	100	60	70	10	30	0	0

TABLE 6.1-4. DATA TRAFFIC DEMAND
PERCENT ACCEPTABLE VS AVAILABILITY

SERVICE	99.99%		99.9%		99.5%		99.0%	
	SAME COST	LESS COST	SAME COST	LESS COST	SAME COST	LESS COST	SAME COST	LESS COST
TWX/TELEX	100	100	90	100	10	20	0	10
FACSIMILE	100	100	90	100	20	50	10	30
EL.MAIL-IMAGE	100	100	100	100	80	90	70	80
EL.MAIL-CHAR.	100	100	100	100	70	80	60	70
TERM/CPU	100	100	70	90	20	30	0	20
CPU/CPU-DIST.PROC.	90	100	70	90	10	20	0	10
CPU/CPU-EFT	100	100	90	100	60	80	50	70
TELECONF. IMAGE	100	100	90	100	20	40	0	20
TELECONF. CHAR.	100	100	90	100	20	40	0	20
FREEZE FRAME TV	100	100	90	100	20	40	0	20

As illustrated in Table 6.1-3, the evaluation of acceptability vs availability for video follows a considerably different pattern. Network TV, with its concern over expensive air time, is very sensitive to outages, and interviews with network executives indicate a reluctance to consider any new modes of communications. Accordingly, the acceptability to Network TV of even the highest availability satellite services is assigned a relatively low value, though, as indicated in the table, cost inducement may motivate some reasonable degree of acceptance at the 99.99 percent availability level. The other components of video traffic (i.e., CATV, Videoconferencing, Educational TV, and Health and Public Affairs) are less critical and receive high acceptability ratings in the table. At 99.9 percent availability and below, a progressive falling off in acceptability is indicated, for the reasons discussed above in the case of Network TV and CATV.

For videoconferencing, the need to assemble several participants and to tie up expensive video facilities makes this application, as estimated in Table 6.1-3, somewhat less tolerant of outage than, for example, an ordinary business telephone conversation.

In the case of Data Traffic, Table 6.1-4 lists most components of the traffic as relatively tolerant of availability levels at or above those currently available on the telephone network. This is particularly true of those components such as Electronic Mail which are inherently off-line, and thereby only slightly affected by outages. Some of the Terminal/CPU and CPU/CPU traffic, however, has real-time critical reliability needs, and consequently an appropriate lessening of the acceptability at the level of 99.9 percent and below is indicated.

While many of the components of Data Traffic Demand will find the relatively poor 99.5 percent and 99.0 percent availability levels unacceptable, large segments of traffic, particularly in the electronic mail, facsimile, and electronic funds transfer segments, will find these levels useful, particularly if a cost advantage is offered. As a result, data traffic demand may be expected to survive greater reliability degradation than would be the case for voice or video traffic, and the estimates provided in Table 6.1-4 reflect this consideration.

6.1.4 SUMMARY OF SATELLITE DEMAND VS AVAILABILITY

The tables presented in the previous section characterize the acceptability of various levels of availability for each of the components of traffic comprising voice, video, and data. The present section aggregates these values so that conclusions may be drawn for voice, video, and data as individual services, and for the satellite service as a whole.

In order to accomplish this, the acceptability factors presented in Tables 6.1-2, 6.1-3, and 6.1-4, for each component of traffic are weighted by the relative traffic demands for that component as expressed in Table 2.4-8 and the results are aggregated. This is repeated for each of the years 1980, 1990, and 2000, and the results presented in Table 6.1-5. Table 6.1-5 presents, for each year, the percentage of Voice, Video, and Data Traffic Demand for which the indicated availability offers an attractive target, both at a cost comparable to other competing communications modes, and at a cost substantially lower than other modes. A fourth line, for each of the years represented in the Table, provides acceptability factors for the overall demand as obtained by weighting the voice, video, and data results in accordance with their relative volumes.

The values presented in Table 6.1-5 are not strongly dependent on year. The greatest dependence in this respect is in the video category, reflecting a trend toward less critical traffic as Video Teleconferencing grows relative to the highly critical Network TV component. Even for Video, however, variation from year to year is not of major significance.

The following conclusions may be drawn from Table 6.1-5:

1. High Availability (99.99 percent)

   - Acceptable to virtually all candidate traffic.

   - Cost reduction and/or further improvement in availability produces negligible increase in acceptability.

2. Medium Availability (99.9 percent)

   - Acceptable to most, but not all, of the candidate traffic.

   - Cost reduction can improve acceptability, but not to the levels achieved with high availability above.

TABLE 6.1-5. SUMMARY PERCENT ACCEPTABLE VS AVAILABILITY

	DEMAND TERABITS/YR.	99.99%		99.9%		99.5%		99.0%	
		SAME COST	LESS COST	SAME COST	LESS COST	SAME COST	LESS COST	SAME COST	LESS COST
1980									
VOICE	559,000	100	100	96	100	6	23	0	10
VIDEO	83,000	82	90	38	55	2	13	0	0
DATA	112,000	99	100	70	90	20	30	0	20
TOTAL	754,000	98	99	86	94	8	23	0	8
1990									
VOICE	1,401,000	100	100	96	100	6	23	0	10
VIDEO	171,000	91	94	57	69	2	14	0	0
DATA	280,000	100	100	71	90	21	31	2	21
TOTAL	1,852,000	99	99	89	96	8	23	3	11
2000									
VOICE	2,893,000	100	100	95	100	5	22	0	10
VIDEO	418,000	97	98	65	76	3	16	0	0
DATA	437,000	99	100	71	90	20	30	1	20
TOTAL	3,748,000	99.5	99.8	89	96	7	22	1	10

3. Low Availability (99.5 percent and 99.0 percent)

- Acceptable to only a minor fraction of the candidate traffic.

- Cost reduction has a significant impact on acceptability and results in the satisfaction of nearly one-quarter of the potential traffic at 99.9 percent availability.

As a general conclusion it appears that the improvement of availability has greater significance than the lowering costs.

6.2 REAL-TIME VS DEFERRED TRAFFIC DEMAND

An important factor in the design of a communications system is the degree to which real-time response is required. Real-time transmissions intensify the inefficiencies inherent in designing for peak hour demands, while deferred traffic allows greater efficiency by permitting use of the facilities provided during off-peak hours. This section examines traffic demand with respect to user requirements for real-time as opposed to deferred (store and forward) transmissions.

6.2.1 CHARACTERIZATION OF REAL-TIME AND DEFERRED COMMUNICATIONS MODES

Real-time usage implies immediate transmission of the signal from user to user. In practice, however, some delays are induced by propagation time, or by the transmission mode (for example, packetized voice). These are generally accepted within the definition of real-time as long as the delays remain a fraction of a second or less. The major contributor to real-time traffic is Voice, but other important traffic segments with real-time demands exist in the Video and Data categories as well.

Systems for deferred traffic may be designed for a wide range of delays. For convenience in estimating demand, deferred traffic was considered under three categories corresponding to delays in the order of minutes, hours, or one day.

Delays in the order of minutes do not allow much latitude in reassigning traffic to less busy hours, but nevertheless permit some design economies in the form of packet transmission or other forms of dense packing of bits. Many applications of facsimile service fall in this category as does some of the inquiry mode data traffic, and the more urgent components of electronic mail.

User tolerance for delays of several hours results in substantial system economy by off-loading peak hour traffic. Many communications applications can profitably use, and in some cases may even require, such delays (for example, store and forward traffic to an office which, because of time zone differences, will not open for some hours). Much of the electronic mail and computer type traffic such as that used in Electronic Funds Transfer applications is in this category. In addition, some transmissions to off-line storage media (such as magnetic tape) for later replay can profitably tolerate several hours of delay, and candidate traffic of this type will be found in the Video area.

The last category of deferred traffic (delays up to one day) permits overnight transmission and is, in many respects, similar to the "Express Mail" service currently offered by the U.S. Postal Service. Candidates for this type of service include the less urgent segments of electronic mail and the various video signals transmitted to storage media for later replay.

6.2.2 METHODOLOGY FOR ESTIMATING DEMAND FOR REAL-TIME VS DEFERRED COMMUNICATIONS MODES

The overall methodology followed in estimating user requirements for real-time vs deferred traffic is similar to that used in the previous discussion of service demand vs availability. Estimates of user requirements for each of the types of traffic included under Voice, Video, and Data were formed by considering the relative mix of communications applications contributing to the traffic. Independent estimates by several investigators were formed and a consensus of results arrived at. The results provide estimates for the percentage of traffic for which real-time response is needed and the percentages for which delays in the order of minutes, hours, and one day are suitable. An underlying assumption in arriving at these figures is that the longer the delay, the less costly the service, and that consequently a strong economic motivation is offered to users able to accept progressively greater delays.

The percentage of each traffic category for which each level of delay is considered suitable was then weighted by the amount of traffic in each category to arrive at weighted averages for Voice, Video, and Data Traffic Demand as a whole. These, in turn, are further combined to arrive at the percentages of overall satellite suitable demand falling under each delay.

6.2.3 ANALYSIS OF REAL-TIME VS DEFERRED TRAFFIC DEMAND

Estimates of the percentages of the various components contributing to Voice, Video, and Data Traffic for which each level of delay is suitable are presented in Tables 6.2-1, 6.2-2, and 6.2-3. Since these component level estimates are not sensitive to year, only a single set of tables is required.

Table 6.2-1 for voice traffic reflects the fact that voice conversations require real-time channels. The table therefore shows 100 percent in the real-time column and zero in the deferred columns. There has been some recent interest in "store-and-forward voice" as part of the office of the future concept. This refers to the capability of leaving a recording of a voice message for later access by the intended recipient. There will undoubtedly be a growing trend toward use of convenience features of this type, but relative to normal real-time voice traffic the impact is expected to be unimportant.

Table 6.2-2 indicates that while most Video traffic requires real-time response, a substantial component can be deferred by recording of the program material for later replay. For that portion of the traffic that can be deferred, the delays fall in the "hours" or "one day" rather than in the "minutes" category. There appear to be few video applications that, having found deferred modes suitable, cannot benefit from the additional economies inherent in the longer delays. Videoconferencing, however, is similar to voice traffic in requiring real-time response. Videc applications such as emergency and telemedicine covered under the Health and Public Affairs category are also likely to require real-time transmission.

Data traffic, as shown in Table 6.2-3, also has sizable components for which deferred transmission modes are suitable. Aside from TWX/Telex and the various narrowband Teleconferencing components which require real-time service, the remainder of the traffic components have elements for which minutes, hours, or one-day delays are satisfactory. This is particularly the case for Electronic Mail and for Electronic Funds Transfer, both of which can make effective use of a high level of deferred communications.

TABLE 6.2-1. VOICE TRAFFIC DEMAND PERCENT REAL-TIME VS DEFERRED

	REAL-TIME	DEFERRED MINUTES	DEFERRED HOURS	DEFERRED ONE-DAY
MTS RESIDENTIAL	100	0	0	0
MTS BUSINESS	100	0	0	0
WATS	100	0	0	0
PRIVATE LINE	100	0	0	0

COSTS DECREASE →

TABLE 6.2-2. VIDEO TRAFFIC DEMAND PERCENT REAL-TIME VS DEFERRED

	REAL-TIME	DEFERRED MINUTES	DEFERRED HOURS	DEFERRED ONE-DAY
NETWORK TV	60	0	20	20
CATV	50	0	10	40
VIDEOCONFERENCING	100	0	0	0
EDUCATION	50	0	20	30
HEALTH & PUBLIC AFFAIRS	100	0	0	0

COSTS DECREASE →

TABLE 6.2-3. DATA TRAFFIC DEMAND PERCENT REAL-TIME VS DEFERRED

	REAL-TIME	DEFERRED MINUTES	DEFERRED HOURS	DEFERRED ONE-DAY
TWX/TELEX	100	0	0	0
FACSIMILE	50	20	10	20
ELECTRONIC MAIL - IMAGE	10	10	40	40
ELECTRONIC MAIL - CHARACTER	10	10	40	40
TERMINAL/CPU	60	20	20	0
CPU/CPU DIST. PROCESSING	50	20	20	10
CPU/CPU - EFT	10	20	40	30
TELECONFERENCE - IMAGE	100	0	0	0
TELECONFERENCE - CHARACTER	100	0	0	0
FREEZE FRAME TV	100	0	0	0

COSTS DECREASE →

6.2.4 SUMMARY OF REAL-TIME VS DEFERRED TRAFFIC DEMAND

The previously presented tables are weighted by the traffic volumes contained in Table 2.4-8 to arrive at aggregate values for the percentages of Voice, Video, and Data Traffic falling in each delay category. This is repeated for the traffic values predicted for each of the years 1980, 1990, and 2000. The results are presented in Table 6.2-4 for each service, with a fourth line for each year presenting the weighted percentages of total traffic for the composite mix.

Most of the traffic categories included in Table 6.2-4 change only slightly with time. The major exception is Video traffic which, because of the growth of Video Teleconferencing, moves moderately toward a greater percentage of real-time demand as time progresses.

For all components of traffic, the major requirement is for real-time service. Data traffic provides the highest overall demand for deferred traffic amounting to roughly 40 percent of the volume, but most of this is in the minutes to hours delay categories. Video traffic has a lower proportion of deferred traffic, but much of its demand for deferred traffic falls in the hours to one-day delay categories, allowing convenient use of off-peak night time capacity.

Total traffic, which tends to be dominated by the large component of real-time voice traffic, presents approximately 90 percent of the demand in the real-time category and has relatively small demands for service in each of the deferred delay categories.

TABLE 6.2-4. SUMMARY
PERCENT REAL-TIME VS DEFERRED TRAFFIC DEMAND

	DEMAND TERABITS/YR.	REAL-TIME	DEFERRED		
			MINUTES	HOURS	ONE-DAY
1980					
VOICE	559,000	100	0	0	0
VIDEO	83,000	53	0	14	33
DATA	112,000	60	20	20	0
TOTAL	754,000	89	3	5	4
1990					
VOICE	1,401,000	100	0	0	0
VIDEO	171,000	76	0	8	16
DATA	280,000	59	20	20	1
TOTAL	1,852,000	91	3	4	2
2000					
VOICE	2,893,000	100	0	0	0
VIDEO	418,000	80	0	7	13
DATA	437,000	58	20	20	2
TOTAL	3,748,000	93	2	3	2

COSTS DECREASE →

6.3 DEMAND FOR SATELLITE TRANSPONDERS

Total annual demand for long distance communications in support of Voice, Video, and Data Services has been presented in Sections 2.1, 2.2, and 2.3. In Section 2.4 these demand forecasts are summarized and aggregated using terabits per year as a common digital unit of measure. The present section extends these forecasts to derive busy hour traffic rates and the number of transponders needed to carry that portion of the traffic likely to be captured by satellite systems.

The problem is approached by first calculating traffic rates during an average hour, and then applying peak factors appropriate to each traffic component. The result, expressed in megabits per second, is the traffic rate prevailing during the busy hour.

Busy hour traffic is shared between terrestrial and satellite systems. That portion of the traffic likely to be carried by satellite systems is of prime concern in this study and capture ratios for each of the service categories are estimated.

Finally, the busy hour traffic projected as an attractive target for satellite transmission is compared with the throughput capabilities of advanced satellite transponders to derive the number of transponders that will be needed in the years 1980 through 2000.

6.3.1 APPLICATION OF PEAK FACTORS TO DERIVE BUSY HOUR TRAFFIC

Traffic demand, as expressed in previous sections of this report, is indicative of the total annual flow of traffic that must be supported by the long distance communications plant. However, in exploring the capacity for which the communications plant must be designed, it is necessary to take into account the fact that demand fluctuates from day to day and from hour to hour, with heavy concentrations of traffic resulting at particular times. Common engineering practice is to design the communications plant to accommodate the traffic levels occurring in the busy hour of a typical day. This is generally approached by applying a peak hour to average hour factor as appropriate to each category of traffic. The result, as developed in the following sections, converts traffic demand, as expressed in terabits per year, into the number of megabits per second carried by the communications plant during the busy hour.

6.3.1.1 Busy Hour Voice Traffic

Peak factors for Voice traffic were discussed in Section 2.1 and are summarized in Table 6.3-1.

TABLE 6.3-1. BUSY HOUR VOICE TRAFFIC

1980

	Annual Traffic (1) (Terabits/Year)	Traffic Rate (2) During Avg. Hr. (Megabits/Sec.)	Peak (3) Factor	Traffic Rate During Busy Hr. (Megabits/Sec.)
MTS Residential	81,000	2,568	.44	1,130
MTS Business	88,000	4,074	3.1	12,630
WATS	160,000	7,407	3.1	22,963
Private Lines	230,000	7,293	1.0	7,293
Total	559,000	21,342	-	44,016

1990

MTS Residential	197,000	6,247	.44	2,749
MTS Business	230,000	10,648	3.1	33,009
WATS	369,000	17,083	3.1	52,958
Private Lines	605,000	19,184	1.0	19,184
Total	1,401,000	53,162	-	107,900

2000

MTS Residential	378,000	11,986	.44	5,274
MTS Business	502,000	23,241	3.1	72,046
WATS	572,000	26,481	3.1	82,093
Private Lines	1,441,000	45,694	1.0	45,694
Total	2,893,000	107,402	-	205,107

(1) From Table 2.4-2.
(2) MTS Residential and Private Lines based on 24 hrs./day, 365 days/yr. MTS Business and WATS based on 24 hrs./day, 250 days/yr.
(3) MTS and WATS peak factors have been increased to account for additional trunk allocations necessary to maintain adequate grade of service.

With respect to MTS traffic, the situation is slightly complicated by the fact that the business and residential components of MTS traffic have their peaks at different hours of the day. However, when Data and Video components as well as other Voice components of traffic are included, traffic at the

business peak hour is found to dominate that at the residential peak. As a result, the two components of MTS traffic are associated in Table 6.3-1 with factors which reflect (a) peak MTS business traffic levels occurring during business peak hours, and (b) off-peak MTS residential traffic that exists during the same time period.

WATS traffic is assumed to have the same peak hour to average hour traffic as MTS business traffic. Private lines are considered to require full time, 24-hour per day, service since the communications capacity must be reserved for these lines whether or not they are actually occupied by traffic.

6.3.1.2 Busy Hour Video Traffic

Busy hour Video traffic is developed in Table 6.3-2.

TABLE 6.3-2. BUSY HOUR VIDEO TRAFFIC

1980

	Annual Traffic(1) Terabits/Year)	Traffic Rate During Avg.Hr.(2) (Megabits/Sec.)	Peak Factor	Traffic Rate During Busy Hr. (Megabits/Sec.)
Network TV	13,200	419	1.0	419
CATV	46,400	1,470	1.0	1,470
Videoconference	3,000	139	2.66	369
Educational	19,900	631	1.0	631
Health & Pub.Affairs	0	0	2.66	0
Total	83,500	2,660	--	2,890

1990

Network TV	15,900	504	1.0	504
CATV	33,100	1,050	1.0	1,050
Videoconference	83,700	3,880	2.66	10,300
Educational	36,400	1,150	1.0	1,150
Health & Pub.Affairs	1,600	71	2.66	189
Total	170,700	6,650	--	13,200

2000

Network TV	10,600	336	1.0	336
CATV	26,500	840	1.0	840
Videoconference	267,800	12,400	2.66	33,000
Educational	110,400	3,501	1.0	3,501
Health & Pub.Affairs	2,200	98	2.66	361
Total	417,000	17,200	--	37,900

(1) From Table 2.4-5.
(2) Network TV, CATV, and Educational TV based on 24 hrs/day, 365 days/yr.
Videoconferencing based on 24 hrs./day, 250 days/yr.
Health and Public Affairs based on 40 hrs./week, 52 weeks/yr.

The first column presents annual traffic as obtained from Table 2.4-5. Network TV, CATV and Educational uses are each assumed to require full time dedicated service. The average hour traffic for these is therefore calculated on the basis of 365 days per year, 24 hours per day, and no peaking (peak factors equals one) is assumed.

The average hour traffic for Videoconferencing is based on 250 days per year, 24 hours a day. Health and Public Affairs average hour traffic is based on 40 hours per week of usage. Peak factors for both Videoconferencing and Health and Public Affairs uses are calculated by assuming a uniform traffic distribution over a 10 hour business day for Eastern and Central time Zone components (roughly 50 percent of the total traffic) plus a similar distribution delayed by three hours for the Western and Mountain Time zone components (25 percent of the traffic). To this is added a component of traffic (25 percent) to account for East-to-West and West-to-East transmissions, this component being uniformly distributed over the seven business hours overlapping in the two time displaced periods.

6.3.1.3 Busy Hour Data Traffic

Data traffic is primarily business oriented and for the most part exhibits peak hour behavior similar to, but slightly more peaked than business oriented voice traffic.

Table 6.3-3 summarizes the peak factors used and the resultant busy hour traffic. The traffic shown is almost completely dominated by the Terminal/CPU component of data traffic which, because of its relative low efficiences and high degree of peaking, places heavy demands on communications facilities. Other components of Data Traffic shown in this table add comparatively negligible amounts to the total, but are included for completeness.

The peak factor of 4.0 for Terminal/CPU traffic takes into account the concentrations of traffic during particular hours of the business day and allocates an additional eleven percent to allow for the traffic engineering margins necessary to achieve a suitable grade of service. Other components of data traffic with similar peak factors are TWX/Telex and Facsimile.

The Electronic Mail components of message traffic are generally off-line and are therefore distributed more uniformly during the day, with substantial components held over beyond normal business hours for automatic transmission. As a consequence these components have been assigned the relatively low peak factors of 2.0 and 2.5 respectively. The slightly larger

TABLE 6.3-3. BUSY HOUR DATA TRAFFIC

1980

	Annual Traffic[1] (Terabits/Year)	Traffic Rate During Avg.Hr.[2] (Megabits/Sec.)	Peak[3] Factor	Traffic Rate During Busy Hr. (Megabits/Sec.)
TWX/Telex	70.	3.24	4.0	13.0
Facsimile	267.	12.4	4.0	49.4
Elect.Mail-Image[4]	--	--	--	--
Elect.Mail-Char.[4]	--	--	--	--
Terminal/CPU	110,000.	5,090.	4.0	20,400.
CPU/CPU-Distrib.Proc.	1,180.	54.6	3.0	164.
CPU/CPU-E.F.T.	14.	.648	2.0	1.3
Teleconf.-Image	4.3	.199	4.5	.896
Teleconf.-Char.	.01	.0005	4.5	.002
Freeze Frame TV	15.8	.731	5.0	3.66
Total	112,000.	5,170.	--	20,600.

1990

TWX/Telex	7.	.324	4.0	1.30
Facsimile	1,760.	81.3	4.0	325.
Elect.Mail-Image	5,400.	250.	2.0	500.
Elect.Mail-Char.	450.	20.8	2.5	52.0
Terminal/CPU	265,000.	12,300.	4.0	49,100.
CPU/CPU-Distrib.Proc.	7,000.	324.	3.0	972.
CPU/CPU-E.F.T.	60.	2.78	2.0	5.56
Teleconf.-Image	166.	7.69	4.5	34.6
Teleconf.-Char.	.9	.042	4.5	.187
Freeze Frame TV	640.	29.6	5.0	148.
Total	280,000.	13,000.	--	51,100.

2000

TWX/Telex	2.	.093	4.0	.370
Facsimile	4,370.	202.	4.0	809.
Elect.Mail-Image	5,040.	233.	2.0	467.
Elect.Mail-Char.	1,680.	77.8	2.5	194.
Terminal/CPU	389,000.	18,000.	4.0	72,000.
CPU/CPU-Distrib.Proc.	34,000.	1,570.	3.0	4,720.
CPU/CPU-E.F.T.	58.	2.69	2.0	5.37
Teleconf.-Image	416.	19.3	4.5	86.7
Teleconf.-Char.	7.	.324	4.5	1.46
Freeze Frame TV	1,940.	89.8	5.0	449.
Total	437,000.	20,200.	--	78,800.

(1) From Table 2.4-8.

(2) All traffic components based on 24 hours/day, 250 days/week.

(3) Peak factors have been increased to account for additional trunk allocations necessary to maintain adequate grade of service.

(4) Included in other components of data traffic.

value used for the character oriented traffic reflects the fact that some portion of this Electronic Mail component includes real time, interactive messages which are concentrated during normal business hours.

CPU/CPU traffic for Electronic Funds Transfer purposes is similarly of lower time urgency and able to utilize communications facilities outside of normal business hours. A peak factor of 2.0 has therefore been assigned. CPU/CPU traffic for distributed processing shares these characteristics, but also has a more urgent character in some applications where rapidly changing data files are being updated. For this reason, CPU/CPU Distributed Processing traffic has been assigned an intermediate peak factor of 3.0.

Those components of data traffic associated with narrowband teleconferencing (i.e., Teleconferencing-Image, Teleconferencing-Character, and Freeze Frame TV) are associated with relatively high peak factors of 4.5 to 5.0. In addition to having the usual concentration to business hours, teleconferencing requires coordination of several participants in possibly differing time zones with a resultant narrowing of the acceptable window during which scheduling of the conference is convenient to all parties.

6.3.1.4 Summary of Busy Hour Traffic

Table 6.3-4 summarizes and aggregates the previous results and presents annual traffic, the traffic rate during the average hour, and the traffic rate during the busy hour. The values provided in the first two columns pertain to total traffic volumes and therefore are roughly related to potential revenues associated with the various services. This relationship, however, is not necessarily a close one since the mix of facilities (i.e.,dial-up, private line, WATS, packet,etc.) and thus costs, varies from service to service.

The last column of Table 6.3-4 shows the Busy Hour Traffic. These values relate more closely to required communications plant facilities which must generally be sized to handle the busy hour of a typical day. Those traffic components, such as many of the important data service applications which concentrate in a limited time span during the business day receive extra emphasis in terms of facilities needed. Thus, compared with voice services whose combined residential and business components present a more evenly distributed traffic load, data services calls for a larger fraction of the required facilities than might ordinarily be expected.

TABLE 6.3-4. SUMMARY OF BUSY HOUR TRAFFIC

1980

	Annual Traffic (Thousands of Terabits/Year)	Traffic Rate During Avg.Hr. (Megabits/Sec.)	Traffic Rate During Busy Hr. (Megabits/Sec.)
Voice	559	21,300	44,000
Video	84	2,700	2,900
Data	112	5,200	20,600
Total	755	29,200	67,500

1990

Voice	1,401	53,200	107,900
Video	171	6,700	13,200
Data	280	13,000	51,100
Total	1,852	72,900	172,200

2000

Voice	2,893	107,400	205,100
Video	417	17,200	37,900
Data	437	20,200	78,800
Total	3,747	144,800	321,800

6.3.2 SATELLITE COMPONENT OF DEMAND

The annual demand, and busy hour traffic rates, discussed earlier represent total demand for long distance communications in the U.S. Resultant communications loads will be handled by a wide variety of communications organizations and will involve many types of terrestrial and satellite facilities. This section discusses those factors that encourage or discourage the use of satellite facilities and provides estimates of the amount of traffic likely to be carried by satellites.

The assumption is made that cost and reliability factors for satellite communications are excellent and as good as or better than those of other available modes of communications. If particular system designs fall short of this assumption, the tradeoffs between reliability and demand, discussed in Section 6.1, may be used to explore the impact of lesser performance levels.

Among the factors that generally tend to slow the widespread acceptance of satellite communications is the large investment in existing terrestrial plant facilities. Considerable resistance to change is expected because of this on the part of both the common carriers and the users. Equally powerful pressures in the opposite direction, however, will be exerted by the projected rapid expansion of demand. As indicated by the traffic projections summarized in Table 6.3-4, communications demand over the next two decades will grow by almost five to one. It is difficult to see how the existing facilities can economically expand to five times their present size without making substantial use of the high capacity potential available through satellites. Furthermore, of the "new" technologies capable of providing the needed high capacity, satellite communications is the most mature. In comparison to other new technologies such as fiber optics, satellite communications is almost two decades further along on the path from early R&D to practical widespread usage.

Two other general characteristics of the satellite medium are worth noting from the particular viewpoint of the carriers who may own and operate the facilities. The first is that satellite installations are relatively flexible compared to most of the terrestrial communications plant. Capacity can be rapidly added or removed in response to emerging demand by reassigning transponders and relocating earth stations. Satellite transmission costs also tend to be distance nonsensitive, a fact which opens the possibility of pricing strategies very attractive to certain classes of users.

From a very broad viewpoint, the items discussed above generally encourage satellite transmission and favor increased capture of communications traffic by this transmission mode. However, with respect to each of the services discussed in this report, the satellite medium presents special characteristics, both favorable and unfavorable, which influence the fraction of total traffic likely to be sent over satellite facilities. These special characteristics are discussed below and provide background for the capture ratios estimated in Table 6.3-5.

TABLE 6.3-5. PERCENT CAPTURE BY SATELLITE

	1980	1990	2000
Voice	2	15	25
Video	50	60	60
Data	1	50	60

6.3.2.1 Voice Traffic

The chief obstacle to user acceptance of satellite transmission for voice conversations is transmission delay. Round trip delay for satellites in synchronous orbit is close to 0.5 seconds and delays of this magnitude have been found disturbing to users in two ways:

(a) Echoes of a speaker's voice extending more than a few tenths of a second tend to disrupt speech patterns.

(b) A delay in response from the far end can result in overtalking when a speaker prompts for an expected response that may have already been launched.

The first of these problems has traditionally been dealt with by the use of echo suppressors which, while adequate for the shorter delays encountered on terrestrial circuits, are less than satisfactory for satellite links. Recent progress in new forms of echo cancellation devices, however, has been informally reported. The major problem appears to be the lowering of production costs to levels suitable for widespread installation. The second problem referred to above is not likely to have a

technical solution since fundamental speed-of-light limitations are involved. Users can, however, become accustomed to the delay, and with experience find it less disturbing.

In discussing these problems with representatives of AT&T and other carriers, some reluctance to a full commitment to satellite voice service was evident. The consensus appears to be that one-way transmission via satellite would be acceptable, but that at least one direction of the duplex voice channel should be routed via terrestrial facilities.

The relatively low two percent capture ratio postulated in Table 6.3-5 for voice in the year 1980 takes the above considerations into account, and also reflects recent experience in the fill volume typical of existing satellite facilities. The projected growths to 15 percent in 1990 and 25 percent in the year 2000 are predicated on continued progress in the development of economical echo cancellation circuits, an increased degree of acceptance by users as they become accustomed to satellite characteristics, and a relatively high usage of satellites for one-half of the duplex path.

6.3.2.2 Video Traffic

The satellite medium is ideally suited in certain respects to video traffic. The most significant aspect of this relates to the satellite's ability to provide large numbers of wide band channels. Depending on system design, the problems of wide band local distribution can also be favorably addressed by the use of direct-to-user transmissions. Furthermore, broadcast modes, from a single originator to multiple recipients, are easily obtained with satellites and are an important feature for some video users.

On the negative side, operators of Network TV tend to be very conservative with respect to transition to satellite transmission. The high value placed on each minute of commercial TV time requires that heavy motivation be offered before a change from tested and familiar terrestrial facilities will be considered. Similar factors are operative, but to a much lesser extent, for CATV, where substantial employment of satellites already exists.

The newer and rapidly growing uses of video in the areas of Education, Medicine, and Videoconferencing, however, appear to have no special barriers preventing the rapid adoption of a medium which can offer substantial advantages to the applications, and has the capacity to handle the heavy demand projected.

The forecast for capture of a large segment of video traffic by satellites is, therefore, optimistic. As indicated in Table 6.3-5, 50 percent of video traffic is likely to be carried by satellite channels in the early 1980s, with growth to 60 percent occurring in subsequent years.

6.3.2.3 Data Traffic

There are several advantages offered by satellites specific to data communications. The satellite transmission mode expected to prevail over the time frame of this study is itself digital. This provides additional efficiency and convenience in assembling data streams for transmission over the communications link. Aside from possible rain-induced problems for the higher satellite bands, the basic satellite channel offers better error performance than that typical of the more complex, multi-hop paths typical of the terrestrial network. Some of the other characteristics of satellite transmission such as the capabilities for broadcast or multipoint transmission modes, and the availability of wide band channels, that were discussed with respect to video traffic also are advantageous for data traffic.

Delay over the satellite paths is a disadvantage for data traffic, as it is for voice, but to a much lesser extent. Many of today's data communications protocols use echoplex modes in which each character is echoed back to the sender by the terminal or computer at the far end. Since the next character generally cannot be sent until the echoed character has been received at the sender's terminal, long path delays result in an undesirable slowing of the rate at which data can be transmitted. Similar problems also exist with respect to the turnaround time of modems in half-duplex operation and with respect to automatic repeat request methods of error control. Fortunately, most of these problems are amenable to short term solutions that already exist and are avoided entirely under newly developed data communications protocols. The echoplex problem, for example, has been largely taken care of by satellite interface units that return the echoed character locally, thereby emulating full round trip echoplex without incurring the full round trip delay. Newer protocols avoid echoplex operation in favor of more efficient error control methods.

Satellite communications are expected to compete favorably with terrestrial networks. The business community, which accounts for most data communications usage, has in the past been responsive to innovation, and may be expected to transfer to new facilities as they become available, and to the extent that they are cost competitive. Offerings by specialized common carriers have until recently been sparse and this accounts for the low capture percentage indicated in Table 6.3-5 for the year

1980. As newer, and more visible,services such as SBS and XTEN are offered, the percentage of data communications traveling via satellite will grow at an accelerating rate and is projected to reach 60 percent by the year 2000.

6.3.3 FORECAST OF REQUIRED SATELLITE CAPACITY

Table 6.3-6 presents estimates for the capacity needed to support that portion of the Voice, Video and Data Traffic forecast for satellite transmission. The first column of the table is obtained by combining the total annual traffic (as presented in Table 6.3-4) with the percentage of total traffic expected to be captured by satellites (from Table 6.3-5). This results in estimates of the annual traffic in thousands of terabits per year projected for satellite transmission for each year.

TABLE 6.3-6. REQUIRED SATELLITE CAPACITY

	Annual Satellite Traffic (Thous. of Terabits/Year) (1)	Satellite Traffic Rate During Busy Hour (Megabits/Sec.) (2)	Transponder Throughput Capacity (Megabits/Sec.) (3)	Required Number of Advanced Transponders
1980				
Voice	11	880	42	21.0
Video	42	1,450	42	34.5
Data	1	210	42	5.0
TOTAL	54	2,540	42	60.5
1990				
Voice	210	16,190	72	224.9
Video	103	7,920	72	110.0
Data	140	25,550	72	354.9
TOTAL	453	49,660	72	689.8
2000				
Voice	723	51,280	108	474.8
Video	250	22,740	108	210.6
Data	262	47,280	108	437.8
TOTAL	1235	121,300	108	1123.2

(1) Annual traffic from Table 6.3-4 times percent capture by satellite from Table 6.3-5.

(2) Busy Hour traffic rate from Table 6.3-4 times percent capture by satellite from Table 6.3-5.

(3) Digital throughput rate forecast for equivalent 36 MHz transponders.

The second column in Table 6.3-6 shows the satellite throughput capacity required during the busy hour. This is similarly obtained by combining values taken from Tables 6.3-4 and 6.3-5, and is presented in units of megabits per second.

The number of satellite transponders necessary to handle the projected busy hour traffic is readily derived from the busy hour traffic rate shown in Table 6.3-6, once the traffic handling capabilities of typical transponders are defined. A digital capacity of 42 megabits per second is generally accepted as the equivalent of present day 36 MHz satellite transponders. It is likely, however, that over the next decades considerable improvement in this rate will occur as a result of technology advances. Table 6.3-6 postulates that the current 42 Mbps digital rate equivalent to a 36 MHz transponder will grow to 72 Mbps and 108 Mbps by the years 1990 and 2000 respectively. The last column in this table uses these values to predict the number of transponders that will be needed for each year of the forecast.

The number of transponders needed is also shown graphically in Figure 6.3-1. The 23 transponders shown as a dotted

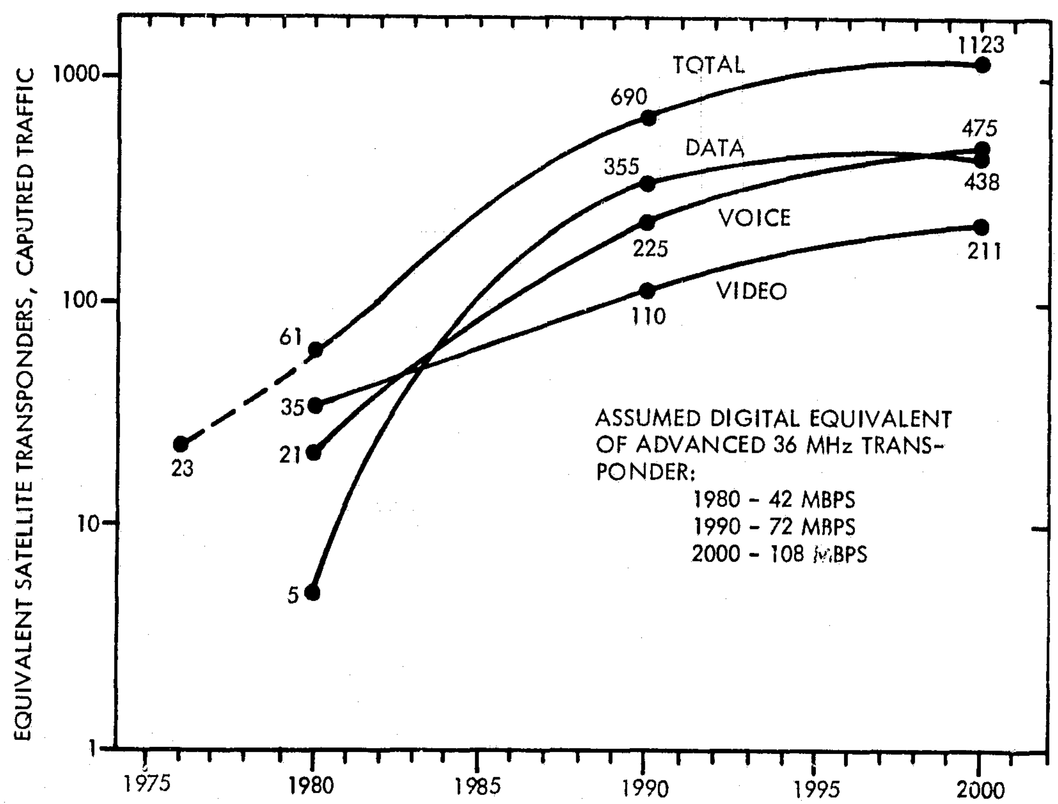


FIGURE 6.3-1. PROJECTED NUMBER OF TRANSPONDERS

line extension curve representing the total is based on historical data for the year 1976. Growth rate is rapid in the first decade, with some signs of saturation occurring during the second decade. It should be noted, however, that a substantial portion of this apparent saturation is the result of postulated technologic improvements in transponder capacity rather than a lessening of the growth rate of underlying demand. The latter growth rates are represented in the totals for annual traffic, and/or busy hour traffic rate shown in the first two columns of Table 6.3-6.

In terms of busy hour demand the average annual growth rate over the twenty year period is 21 percent, while in terms of the number of advanced transponders needed to serve this demand, the average annual growth rate is sixteen percent.

6.3.4 COMPARISON OF TRANSPONDER DEMAND WITH EXPECTED C AND Ku BAND CAPACITY

In Section 5.3 projections were developed for the number of satellite transponders in C and Ku bands that will be in orbit over the time frame of this study. By comparing these projections with total demand for transponders as developed in Section 6.3.3, the time at which C and Ku capacity will become saturated may be determined.

Figure 6.3-2 shows total demand for satellite transponders overlaid on the estimated capacity of C and Ku band satellites. The curve labeled "Increasing Capacity Transponders" refers to advanced transponder design with digital capacity increasing with time as discussed earlier. A most probable target year for saturation of C and Ku band capacity is 1989. The curve labeled "Constant Capacity Transponders" refers to the case in which the digital capacity of nominal 36 MHz transponders remains fixed at 42 MHz. As may be seen from the curves, if technologic advances fail to achieve the projected improvements in transponder digital capacity, the most probable year in which C and Ku systems will become saturated advances to 1987.

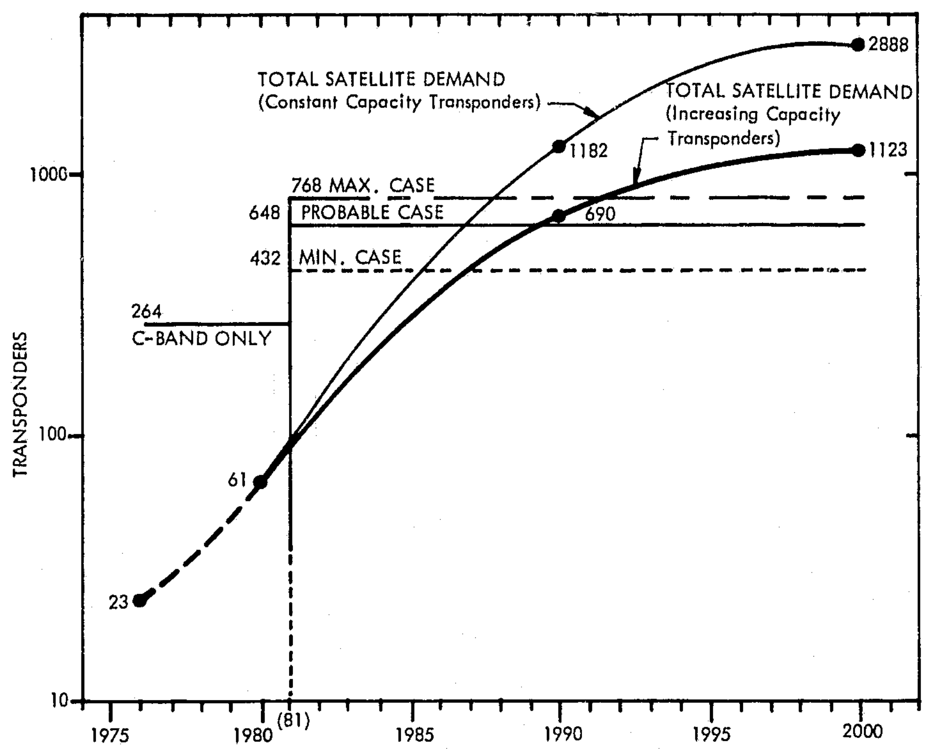


FIGURE 6.3-2. REQUIRED TRANSPONDERS VS C AND Ku CAPACITY

7.0 RESULTS AND CONCLUSIONS

The following discussion summarizes the important results.

7.1 BASIC DEMAND FORECASTS

Over the two decade time span of this study, covering the years 1980 through 2000, demand for telecommunications services extending beyond local (nominally 200 miles) boundaries will grow rapidly. In terms of the total number of bits transmitted per year, demand is projected to grow by a factor of five, and that fraction of the demand most likely to be transmitted via satellite, although starting from a lower base, will expand even more rapidly.

Of the three telecommunications services studied, the Voice Service accounts for the largest fraction of the total annual demand. Video and Data Services are roughly equivalent to each other in magnitude, but combined amount to only about one-third of the demand for Voice Service. Compound growth rates for all three services are comparable. While demand for Video and Data Services, by most measures, is expected to increase at considerably higher rates than demand for Voice, advances in bandwidth compression and packet switching technology will improve the transmission efficiencies of Video and Data to a greater extent than for Voice. Since improved efficiency permits the same information transfer with a smaller expenditure of communications resources, growth rates for Video and Data services over the 20 year forecast period are moderated and growth rates for all three services fall in the seven to nine percent per annum range.

7.2 SATELLITE COMPONENT OF DEMAND

The total annual demand for telecommunications services will be satisfied by a wide variety of communications organizations and only a portion of this demand can be expected to utilize satellite facilities. Among the factors that generally tend to slow the widespread acceptance of satellite communications is the large investment in existing terrestrial plant facilities. Considerable resistance to change is expected because of this on the part of both the common carriers and the users.

Equally powerful pressures in the opposite direction, however, will be exerted by the projected rapid expansion of overall demand which, as previously indicated, will over the next two decades increase by almost five to one. It is difficult to see how existing facilities can economically expand to five times their present size without making substantial use of the high potential capacity available through satellites. Furthermore, of the "new" technologies capable of providing the needed high capacity, satellite communications is the most mature. In comparison

to other new technologies such as fiber optics, satellite communications is almost two decades further along on the path from early R&D to practical widespread usage.

Two other general characteristics of the satellite medium are worth noting from the particular viewpoint of the carriers who may own and operate the facilities. The first is that satellite installations are relatively flexible compared to most of the terrestrial communications plant. Capacity can be rapidly added or removed in response to emerging demand by reassigning transponders and relocating earth stations. Satellite transmission costs also tend to be distance insensitive, a fact which opens the possibility of pricing strategies very attractive to certain classes of users.

Thus, from a broad viewpoint, the items discussed above generally encourage satellite transmission and favor increased capture of communications traffic by this transmission mode. However, with respect to each of the services discussed in this report, the satellite medium presents special characteristics, both favorable and unfavorable, which influence that fraction of total traffic likely to be sent over satellite facilities in support of each service.

The two most important characteristics of satellite channels, bearing on the degree of acceptability for voice, video and data services are (a) reliability and (b) transmission time delay. The first of these is discussed separately in connection with rainstorm induced outages possible in certain designs at the higher satellite transmission frequencies. Assuming that reliability factors for satellite communications are excellent, and that reliability and cost considerations for satellites are as good as or better than those of other available modes of communications, the problem of transmission time delay remains a significant one for satellite links.

The most sensitive of the services to time delay is voice. The round trip time delay for satellites in synchronous orbits is close to 0.5 seconds, and delays of this magnitude plus attendant echoes have been found disturbing to many users. For this reason, projections for the percentage of voice traffic likely to travel via satellite are relatively low (initially, two percent), but are expected to increase to about 25 percent as new echo cancelling circuits become economically feasible.

With respect to video, the satellite medium is well suited to supply the large number of wideband channels required. Furthermore, broadcast modes, from a single originator to multiple recipients, are easily obtained with satellites and this is an important feature for some video applications. Much of the video demand is for one way circuits where time delay is not of

importance. Videoconferencing, however, the most important contributor to demand for video services in the second decade of the forecast, does involve two-way transmission but achieves it through the use of two separate one-way paths. As a result, these transmissions are less subject to echo and delay problems. There appears, therefore, to be no special barriers to the continued adoption of satellite transmissions for most of the video service, which already is at a high level. The high capacity and special advantages offered by satellite communications lead to projections for potential capture starting at about 50 percent and growing to 60 percent of the total demand for video services.

Transmission delay encountered over satellite paths is a disadvantage for data traffic, but to a much lesser extent than for voice. Technical solutions to existing problems are available in the form of special satellite interface circuits, and new data communications protocols are being introduced which completely avoid the delay problem. Satellite communications are therefore expected to compete favorably with terrestrial systems for data traffic. Offerings by specialized common carriers, however, have so far been scarce so that an initially low percentage of one percent with an accelerating growth to 60 percent capture by the year 2000 is projected.

7.3 REQUIRED SATELLITE CAPABILITIES

The number of satellite transponders that will be needed over the period of the forecast is determined by combining total annual demand with the percentage of demand likely to be diverted to satellite transmission. It is also necessary to take into account traffic peaks during the busy hour and the digital throughput capacity of typical transponders. When these steps are taken, growth rates projected for the number of transponders projected during the first decade are found to be high, averaging 28 percent per annum. This, in part, reflects the fact that the satellite portion of demand starts from an appreciable, but relatively low, value and therefore on a percentage basis is initially capable of a high degree of market penetration without substantially impacting overall demand. During the decade between 1990 and the year 2000, some market saturation effects are predicted and annual growth rates, averaged over the decade, moderate to five percent. This projection, however, includes the effects of a predicted improvement in the capability of satellite transponders to achieve higher bit packing in a given bandwidth. Without this additional capability, growth rates during the second decade would continue at an average annual rate of over nine percent.

While voice is the dominant service in terms of overall demand for telecommunications, its influence on the orbital capacity needed for the satellite component of demand is important but not dominant.

7.4 NEED FOR NEW SATELLITE TECHNOLOGY

The capacity of the C and Ku frequency bands to satisfy demand for satellite transmission is limited by technical and regulatory considerations. In the 70 degree orbital arc from 65 to 135 degrees, the most probable spacing for satellites appears to be 4 degrees for C band and 3 degrees for Ku band. Over most of the time span under consideration, this restricts the number of nominal 36 MHz transponders likely to be available for use by the United States to 648 or less.

The equivalent digital transmission rate represented by these transponders depends on the sophistication of the modulation scheme employed. This study assumes that circa 1980 each transponder will support 42 Mbps, but that by 1990 this will have increased to 72 Mbps and by the year 2000 to 108 Mbps.

Under these assumptions the demand for satellite transmission will exceed the capacity of the C and Ku bands by the year 1989. If the forecast increases in the digital capacity of a nominal 36 MHz transponder do not occur, C and Ku band satellite capacity will be exceeded approximately two years earlier.

In either case, new satellite technology to supplement that presently projected for C and Ku bands will be needed for the decade of the 1990s. Preparation for the introduction of the Ka band for this purpose, supported by the use of advanced satellite technology, is strongly indicated.

7.5 GEOGRAPHIC DISTRIBUTION OF TRAFFIC

The distance over which traffic is distributed has an important influence on the viability of satellite communications. Costs for terrestrial facilities increase with distance so that a large component of long haul traffic favors satellite approaches. Since many of the communications applications forecast in this study cannot a priori be expected to follow conventional telephone patterns, parallels were drawn with airline travel and mail distribution. The three distributions (toll telephone, airline and mail) for distances beyond 200 miles were found to follow very similar distributions. Based on these distributions, it is estimated that 50 percent of the traffic extending beyond 200 miles will travel at least 700 miles, and that 37 percent will travel more than 1000 miles, a result favorable to the ability of satellites to compete economically.

The distribution of traffic demand as a function of city size was investigated by considering the fraction of the population that lives in cities of various size categories ranging from small cities of 10,000 population to very large cities.

Approximately 50 percent of the traffic demand is expected to originate in cities of population greater than 100,000 and about 18 percent originates in cities with populations greater than one million.

Cities between 10,000 and 100,000 in population contribute 50 percent of the demand, which means that lower limits to the size of cities that should be addressed will be primarily determined by the economics of distribution to many widespread locations rather than determined by a falling-off of demand from these locations.

7.6 SENSITIVITY OF SERVICE DEMAND TO PRICE VARIATIONS

Elasticity of demand for communications service with respect to price changes depends very strongly on the alternatives available to users. When the communications plant as a whole is considered, demand is relatively inelastic. Values of about -0.2 are suggested in some recent studies of the telephone plant, indicating that a decrease in price of one percent is likely to cause an increase in traffic of only 0.2 percent.

However, when a limited segment of communications is considered (for example, satellite communications), price changes relative to the remainder of the communications plant have a much larger impact on demand. Clearly, if users can select an alternative medium offering comparable service at lesser cost, they will elect the less costly alternative. Demand in this case may therefore be expected to be much more elastic. Some limited studies indicate that price elasticity for a limited segment of the communications plant is about -1.6. While available data does not provide guidance in this respect, it appears likely that this value is most applicable to price decreases of the limited segment below the prevailing rates for the remainder of the communications plant. Under these circumstances, a limited segment of communications offering a price decrement of one percent might be expected to achieve a 1.6 percent increase in volume.

7.7 USER MARKET IDENTIFICATION

Business uses account for the greatest portion of telecommunications demand, amounting to approximately 60 percent of the total. Government and institutional users each account for roughly 15 percent, and private individuals, whose usage is primarily in the voice category, account for the remaining 10 percent.

7.8 CASE STUDY OF A METROPOLITAN AREA

Atlanta was selected as an example of a rapidly growing metropolitan area which offers a good potential market for both existing and innovative telecommunications services.

The seven counties forming the Atlanta telephone free-calling area is referred to in this study as the Atlanta Region. It represents more than 90 percent of the population and employment of the Atlanta SMSA.

In 1976 the Atlanta region included 0.8 percent of the nation's population and 0.9 percent of the nation's employed. civilian, non-agricultural labor force. Current annual population growth rate is about five percent per year, as compared to 0.8 percent for the country as a whole.

The Atlanta region's consumption of telecommunications is also rapidly growing. The number of main telephones in the Atlanta region is currently growing at over eight percent per year while overall for the United States this rate is three percent. Similarly, the number of households with access to CATV cables is higher in Atlanta than the national average.

The Atlanta region was recently chosen by Bell Laboratories as the location for a study of the economics of an all-digital telephone exchange capable of serving a mix of innovative telecommunications services expected for the 1980s. Currently an eight-mile fiber optics link is being implemented by the Southern Bell Telephone Company to supply 45 Mbps capacity in the Atlanta region.

7.9 DEMAND AS A FUNCTION OF RELIABILITY

The impact of reliability on telecommunications demand was evaluated for four levels of availability ranging from an availability (99.99 percent) considerably better than that generally provided by competitive terrestrial communications to one considerably worse (99.0 percent). An availability of 99.9 percent is roughly equivalent to typical terrestrial communications.

About 89 percent of the projected communications demand is estimated to find 99.9 percent availability, an acceptable level of performance. A substantial reduction in cost is estimated to increase demand at this availability level to 96 percent of the total traffic.

An improvement in availability to a level of 99.99 percent will result in a communications service which is estimated to be acceptable to more than 99 percent of the users with or without additional cost inducement.

However, when availability falls below that typical of competing media, demand is predicted to fall rapidly. At an availability of 99.5 percent demand is estimated to be only seven or eight percent of the total and a substantial cost reduction is capable of restoring demand to only the 22 to 23 percent level. The lowest availability level considered (99.0 percent) is predicted to satisfy at most a few percent of the communications applications and cost reductions will be an effective inducement in restoring only 10 percent of the demand.

7.10 REAL-TIME VS DEFERRED TRAFFIC DEMAND

Over the time frame of the study, demand for real-time traffic accounts for 89 to 93 percent of the total.

Voice traffic is exclusively real time, but both the Video and the Data categories offer the opportunity of offering some service at delays ranging from minutes to one day.

The Data service is the most tolerant of deferred transmission modes with applications such as Electronic Mail, and Electronic Funds Transfer providing substantial traffic in the deferred categories. About 40 percent of Data traffic can be deferred and of this about half can tolerate delays of several hours or more.

7.11 SUMMARY OF CONCLUSIONS

It appears clear that demand for telecommunications in general, and for satellite communications in particular, will increase by substantial factors over the next two decades. Voice services over this period will continue to account for the most significant fraction of the overall demand for telecommunications. Voice services also represent a major fraction of projected satellite capacity requirements, but the Video and Data components are of comparable significance.

New communications facilities should be designed to achieve levels of reliability at least equal to typical terrestrial facilities but need not be appreciably better in order to be effective. While some traffic can be deferred to off-peak hours, the bulk of the traffic projected will require real-time transmission capabilities and future designs should reflect this division of traffic.

The distances over which traffic is projected to be transmitted are relatively large, a factor which is generally favorable to competition for traffic by satellite facilities. Substantial markets exist in urban areas of all sizes and a decision to serve cities down to a particular size category rests on the economics of distributing service down to that level rather than to a lack of total demand among these cities.

The capacity of the C and Ku satellite bands to handle the projected demand is limited and will be exceeded prior to the decade of the 1990s. Steps necessary to introduce new satellite technology, and to develop the Ka band for commercial transmission, should be taken in time to respond to the emerging demand forecast in this study.

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